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Measuring and fostering text-learning strategies and graphical summarization skills at the end of elementary school. Comparing the impact of researcher-provided and student-generated mind maps.

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1 General introduction

Chapter 1
General introduction

Abstract

The present dissertation starts with a general overview of the research theme and the different research studies that are presented in chapter 2 to 9. After a general introduction, two major considerations resulting from learning strategy research are described, resulting in two consecutive lines of research. Further, the main research objectives of each empirical study included in this dissertation are outlined. The introduction concludes with an overview of the methodological approaches applied in each study and a visualization of the dissertation structure.

Introduction

The ability to learn and 'learn how to learn' is one of the basic skills to social and economic success in the 21st century (Anderson, 2008; Hoskins & Crick, 2010; OECD, 2010). In this respect, the last decades have been typified by an exponential knowledge and information increase and an explosion of content to be taught in classrooms (Anderson, 2008; Fulk, 2000). It is therefore essential to guide students towards high levels of awareness about which strategies are most effective for understanding, remembering and summarizing information, as this helps them to learn more effectively and attain better outcomes (OECD, 2010). Furthermore, students should be guided to apply these strategies spontaneously in a self-directed way, regulating their own learning processes as efficiently as possible (Könings, Brand-Gruwel, & van Merriënboer, 2005; Rawson & Dunlosky, 2007). Initiating students to self-regulate their academic studying becomes especially important when students transit from elementary to secondary school. Here, pre-adolescents are faced with more and higher academic demands, such as new to be learned subjects, the frequent use of informative texts to reach instructional objectives and increased expectations for independent text study (Broer, Aarnoutse, Kieviet, & Van Leeuwe, 2002; Duchesne, Ratelle & Roy, 2011; Meneghetti, De Beni, & Cornoldi, 2007). Therefore, initiating a broad repertoire of learning strategies to support this text-based learning (i.e., processing and acquiring knowledge from informative texts) arises as an important educational goal in late elementary grades (McNamara, Ozuru, Best, & O'Reilly, 2007). This is also reflected in the Flemish cross-curricular attainment targets of 'learning to learn' (Department of Education and Training, 2008). Consequently, this dissertation builds upon the importance and stimulation of text-learning strategies in fifth and sixth grade of elementary education in Flanders (Belgium). The map on the following page (Figure 1), to be read clockwise, gives an overview of this chapter's structure, which will be elaborated on in detail on the next pages.

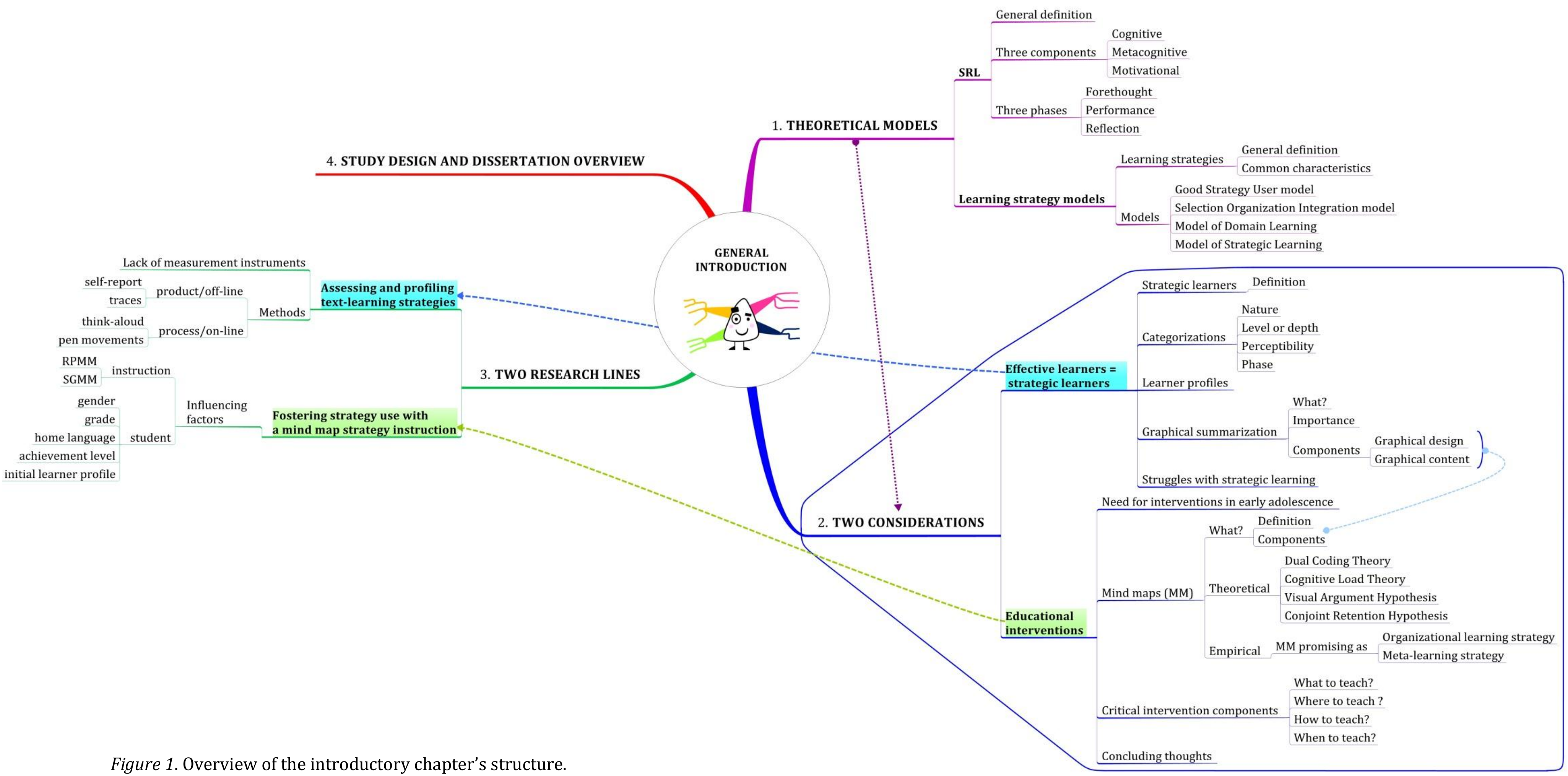

Figure 1. Overview of the introductory chapter's structure.

Theoretical models of self-regulated learning and strategy research

Self-regulated learning

"Possession of effective learning-to-learn skills is an important prerequisite for effective lifelong learning to occur" (Cornford, 2002, p. 367). From a domain-general viewpoint, the concept of 'learning to learn' and importance of text-learning strategies can be broadly situated within the framework of self-regulated learning. This concept plays a very important role in educational research literature (e.g., Alexander, Dinsmore, Parkinson, & Winters, 2011; Donker, de Boer, Kostons, Dignath van Ewijk, & van der Werf, 2014), wherein several comprehensive models of self-regulated learning are proposed (e.g., Boekaerts, 1999; Pintrich, 2000; Winne & Hadwin, 1998; for an overview see Puustinen & Pulkkinnen, 2001). Overall, self-regulated learning refers to a planned and cyclical way of regulating thoughts, feelings and actions to meet personal goals (Black, McCormick, James, & Pedder, 2006; Boekaerts, Pintrich, & Zeidner, 2000; Dignath, Buettner, & Langfeldt, 2008; Zimmerman & Schunk, 2001). In this respect, education is required to develop active strategic learners, approaching their learning in an independent, active and constructive way (Boekaerts et al., 2000; Cornford, 2002).

Self-regulated learners are characterized by three important characteristics: They are metacognitive active participants in their learning process, motivated to learn and strategic (Winne & Perry, 2000; Zimmerman, 1986). First, self-regulated learners act in a metacognitive way as they evaluate their strengths and weaknesses to optimize their learning. In this respect, they apply strategies for planning, monitoring and evaluating their learning process and outcomes (Pintrich, 2004; Zimmerman, 1990). Second, they are motivated to learn as they are persistent in learning to achieve personal progress and deep understanding. This characteristic refers to the motivational component of self-regulated learning, which relates to students' reasons for performing a task (Pintrich, 2004). Self-efficacy, intrinsic motivation, attributions and goal orientations are regarded as important key elements within students motivation (Linnenbrink & Pintrich, 2002). Third, they are strategic, as they apply a repertoire of strategies appropriately (Winne & Perry, 2000; Perry & Rahim, 2011). These strategies to effectively process and acquire information refer to the cognitive component of self-regulated learning (Pintrich, 2004).

Pintrich (2000) also comprehensively describes a series of phases a learner follows while integrating these three components during task performance, that is (a) the forethought phase, (b) the performance phase, and (c) the reflection phase (Pintrich, 2000). During the forethought phase influencing processes precede students' actions. Self-regulatory activities in this phase involve task-analysis (i.e., goal setting, strategic planning) and self-motivational beliefs (e.g., self-efficacy, intrinsic interest). Self-regulatory activities embedded within the performance phase, refer to processes undertaken during students' action. For example, students can engage in learning strategies or self-monitoring. The reflection-phase contains processes after students' performance efforts, such as self-evaluation (Pintrich, 2000).

Learning strategy models

The application of learning strategies represent a key component in different models of self-regulated learning. Those strategies can be defined as “any behavioral, cognitive, metacognitive, motivational or affective process or action that facilitates understanding, learning, and meaningful encoding into memory” (Weinstein, Jung, & Acee, 2011, p. 137). Learning strategies share some common characteristics in this respect, as they are all believed to be procedural, purposeful, effortful, willful, essential and facilitative. They entail procedural knowledge (‘how to’ knowledge) and are purposefully applied. Strategies are essential tools in learning and entail planful engagement in learning as they require time and mental energy commitment. Further, they are facilitative in a way they promote deeper and better understanding (Alexander, 1998; Alexander & Jetton, 2000; Warr & Allan, 1998). Consequently, strategies can be regarded as very important tools to regulate and enhance learning from texts (Alexander & Jetton, 2000). Besides the general comprehensive models of self-regulated learning, more domain-specific learning strategy models have been developed, each with a different focus. In the next sections, relevant models regarding strategy use during learning from texts are subsequently described, that is the ‘Good Strategy User (GSU) model’ (Pressley, Borkowski, & Schneider, 1987), the ‘Selection Organization Integration (SOI)-model’ (Mayer, 1996), the ‘Model of Domain Learning (MDL)’ (1998), and the ‘Model of Strategic Learning (MSL)’ (Weinstein, Jung, et al., 2011).

Pressley and colleagues (1987) focus in their ‘*Good Strategy User (GSU) model*’ on five identified components of good strategy users: (1) The GSU can exert many strategies to attain goals. Pressley et al. (1987) refer in this respect to the interplay between goal-specific strategies (e.g., summarizing), monitoring strategies (e.g., checking progress) and higher-order strategies (e.g., applying a self-controlled strategic sequence in the former strategies); (2) The GSU has metacognitive knowledge about specific strategies, that is knowing how, when, and where to apply these techniques; (3) The GSU understand that good performance is tied to personal effort expended in carrying out appropriate strategies; (4) The GSU possesses a non-strategic knowledge base (e.g., knowledge of the alphabet, the existence of categorizations); (5) The GSU has automatized the first four components and their coordination (Pressley et al., 1987). Young children possess very limited strategy knowledge and tendencies, while mature learners thoroughly understand and apply a wide range of strategies. Based on the GSU model, Pressley et al. (1990) developed a model for strategy instruction, involving training teachers in engaging students in cognitive and metacognitive strategies to be used in text learning (e.g., memory strategies, monitoring). Later on, Pressley and Schneider (1989) accommodate this model to ‘the good information processor (GIP) model’, defining strategies, knowledge, metacognition, motivation and short-term memory capacity as essential components for good information processing (Pressley, 1994; Pressley & Scheider, 1989).

At the end of the 90’s, Mayer (1996) introduced a cognitive-constructivist vision on text learning by postulating his ‘*Selection Organization Integration (SOI)- model*’. In this model, learners are actively involved in three crucial cognitive processes to make sense out of expository or informative texts, that is selecting relevant information, organizing this information into a coherent representation, and integrating the information within the existing knowledge (Mayer, 1996). When intending to teach students how to make sense out of informative texts, students should participate in these essential processes within the context of authentic academic tasks (Mayer, 1996). Based on this SOI-model, Mayer (1999) describes educational techniques encouraging each of these three crucial processes, such as highlighting or underlining important information, using headings, printing words in italics or boldface (encouraging selection), paying attention to pointer words (e.g., 'In a first step, in a second step…'), adding graphic representations to text (encouraging organization), and using elaborative questions (e.g., explaining concepts in familiar terms) and captioned illustrations (encouraging integration).

The *'Model of Domain Learning (MDL)'* was described by Alexander (1998) and describes learning from text through a developmental lens. Based on research on knowledge acquisition, strategic processing, motivation and expertise, text-based domain learning is described through three different stages (Alexander, 1998, 2003). More particularly, the MDL describes how learners progress from acclimation through competence to proficiency-expertise when they read and learn in certain domains. Knowledge, strategies and interest are identified as three interplaying factors configuring differently during the progression through these stages (Alexander, 2003). Acclimated or novice learners are characterized by their limited or fragmented knowledge, frequent use of surface-level strategies (e.g., rereading paraphrasing) and low personal investment in the academic domain. These learners generally apply rather surface-level strategies to make sense of the text, for example, they cannot discern between more and less important information or cannot detect irrelevant or misleading information (Alexander, 1998, 2003). Competent learners have progressed through this initial acclimation stage. Those learners possess an improved and more cohesive knowledge base, and already utilize more efficient and effective general strategies (i.e., they can overcome perceived comprehension problems, and identify pertinent information). Furthermore, they show an enhanced subject matter interest. Proficient or expert learners combine a high cohesive, deep and broad body of domain knowledge, with a refined strategic repertoire and a lasting interest and personal investment. Alexander, Murphy, Woods, Duhon, and Parker (1997) stress the importance of including strategy instruction into subject-specific interventions.

Finally, Weinstein, Jung and Acee's (2011) *Model of Strategic Learning (MSL)* summarizes three interacting components of autonomous and strategic academic learning (i.e., skill, will and self-regulation). 'Skill' refers to the knowledge about, how and when to apply learning strategies (i.e., respectively declarative, procedural and conditional knowledge). In this respect, Weinstein, Jung, and Acee (2011) refer to Weinstein and Mayer's (1986) basic learning strategy taxonomy, distinguishing strategies into four categories: rehearsal, organization, elaboration, and monitoring. Repeating something over and over and reviewing highlighted material are types of passive and active rehearsal strategies, typically aimed at basic memorization and surface level information processing. Organization entails strategies students use to group, relate or order information in the learning material into another configuration (e.g., summarizing, diagramming). Elaboration refers to strategies for building connections between the text material and information located in other sources (e.g., making associations with relevant prior knowledge). Both elaboration and organization strategies facilitate deep-processing and meaningful learning of the information (Weinstein, Jung, et al., 2011). Finally, monitoring (Weinstein & Mayer, 1986) (renamed to 'self-regulation strategies' into their later work; Weinstein, Jung et al., 2011) refers to the assessment and regulation of the learning process (e.g., comprehension confirmation, comprehension monitoring, motivational regulation) (Weinstein, Jung, et al., 2011; Weinstein, Husman, & Dierking, 2000; Weinstein & Mayer, 1986). 'Will' is, next to skill, a second important motivational affective component within strategic learning, relating to students' attitudes beliefs and goals that drive students' learning. Self-regulation is the third component with the MSL, helping students to manage their learning process at a global and real-time level. The global-level includes a systematic approach to learning, managing motivation to learn. The real-time level includes for example monitoring and regulating the use of learning strategies and focusing attention (Weinstein, Jung, et al., 2011; Weinstein, Acee, Jung & Dearman, 2011). Each of the three components have causative relationships with achievement and retention, account for a meaningful amount of variance in academic achievement and retention and is amenable for some type of educational intervention (Weinstein, Acee, et al., 2011).

Two important considerations

Strategic processing and the application of learning strategies represent key components in the abovementioned theoretical models developed within the last decades of strategy research. Despite their different focus and specific properties, two important considerations can be drawn from the above outlined overview of theoretical models, that is 'effective learners are strategic learners' and 'educational interventions should introduce learners in this strategic learning'. These two considerations led us each to particular educational research lines. These considerations and research lines will be subsequently discussed on the following pages.

Effective learners are strategic learners

All described theoretical models point at the importance of a rich strategic repertoire (Pressley et al., 1987; Mayer, 1996; Alexander, 1998; Weinstein, Jung, et al., 2011), which is explicitly put forward in the last, most recent Model of Strategic Learning (Weinstein, Jung, et al., 2011). Although the term 'strategic' may involve several complex interacting factors, the basic of strategic learning is that students possess a flexible arsenal of learning strategies useful in studying (OECD, 2010; Simpson & Nist, 2000). Hence, strategic learners apply a diverse repertoire of learning strategies.

Learning strategy categorizations

Learning strategies are categorized in many ways within these theoretical models. A first categorization can be found in the GSU-, SOI-, and MSL-model, wherein strategies are categorized upon their nature. In this respect, learning strategies are distinguished into cognitive (e.g., tactics to process and acquire information), metacognitive (e.g., planning, monitoring, evaluating), and motivational strategies (e.g., self-efficacy, beliefs), reflecting the essential components of self-regulated learning (Pintrich, 2004; Schraw, 1998). Strongly similar categorizations can be found in the work of other empirical learning strategy researchers who do not position a distinct theoretical model. Warr and Downing (2000), for example, distinguish cognitive (e.g., organization), behavioral (e.g., help-seeking), and self-regulatory strategies (e.g., emotion control), and Vermunt (1996) discerns cognitive (e.g., structuring), affective (e.g., concentrating) and regulative strategies (e.g., orienting). Here, a great overlap is shown, as each learning strategy or activity is in essence either more cognitive, metacognitive, or motivational-affective in nature.

A second categorization is based upon the level or depth of strategy use, referring to the degree to which students actively engage in knowledge transformation. This is the case in the 'Model of Domain Learning' (Alexander et al., 1997; Alexander, 1998), wherein surface-level and deep-level strategies are distinguished. Surface-level strategies encompass reproductive strategies, primarily aimed at basic memorization or rote learning (e.g., repeatedly reading or literally copying texts), whereas deep-level strategies reflect the transformation or application of information and results in meaningful learning (e.g., summarizing, creating diagrams) Also other researchers align with this categorization in their learning strategy research (Alexander et al., 2011; Ausubel, 1968; Broekkamp & Van Hout-Wolters, 2007; Lahtinen, Lonka, & Lindblom-Ylänne, 1997; Nesbit & Adesope, 2006).

A third categorization is based upon the strategies' perceptibility. In this respect, learning strategies can be used overtly or covertly. Overtly used strategies are observable, that is, they produce physical records or artifacts (e.g., text notes or summaries). Covertly used strategies are less or not observable. These are internal mental-learning processes, such as mental rehearsal. Although this way of categorizing strategies is not that explicitly addressed and more implicitly present in the described theoretical models, educational research has already regularly drawn upon this distinction to study learning from text (Kardash & Amlund, 1991; Lahtinen et al., 1997; Wade, Trathen, & Schraw, 1990).

A fourth way to categorize learning strategies is based upon the learning phase wherein they are applied, namely before, during or after learning (Broekkamp & Van Hout-Wolters, 2007; Schellings, 2011). This categorization aligns with the learning phases described by Pintrich (2000). Other researchers, however, consider learning strategies to be interwoven, taking place at multiple stages of the text-learning process (McNamara et al., 2007).

Learner profile

Various studies have thus endeavored to conceptualize and categorize learning strategies in many ways. This endeavor has in turn inspired researchers to explore the existence of different approaches to learning or 'learner profiles', wherein students combine different self-regulatory processes and text-learning strategies in a certain way (Abar & Loken, 2010; Rheinberg, Vollmeyer, & Rollett, 2002; Turner, Thorpe, & Meyer, 1998; Wade et al., 1990).

For example, Abar and Loken (2010) distinguish between three self-regulated learner profiles (i.e., the high, average and low SRL group) among secondary students, by investigating the combination of different measures of self-regulated learning (e.g., metacognition, effort management, time and study environment, anxiety, goal orientation). Wade and colleagues (1990) describe six distinct clusters of studiers among college students, reflecting different ways of studying texts (i.e., the good strategy users, text noters, information organizers, mental integrators, memorizers and flexible readers). Also international comparative research (OECD, 2010) has identified six profiles among secondary students (i.e., deep and wide readers, deep and narrow readers, deep and highly restricted readers, surface and wide readers, surface and narrow readers, surface and highly restricted readers). Here students' reading and learning habits are characterized according to a width dimension (i.e., range of reading habits) and depth dimension (i.e., level of effective learning strategies) (OECD, 2010).

Examining these profiles or strategy repertoires contributes in an important way to educational research and practice. It allows educational researchers to observe differential study patterns, wherein strategy application is manifested in different ways. These study patterns are not always immediately visible (Abar & Loken, 2010; Wade et al., 1990). Practitioners can call upon these insights, not merely for classifying students into or conforming them to a specific cluster, but to examine how well text-learning strategies are used, to help students consider available strategies, to instigate their awareness of the value and usefulness of strategies and to instruct them in how and when to apply them effectively (Wade et al., 1990).

Graphical summarization: An indispensable deep-level strategy

> "High-performing countries are also those whose students generally know how to summarize information" (OECD, 2010, p. 14).

The previous overview has illustrated that a wide range of text-learning strategies are at students' disposal to process and learn text, to be combined in many ways. Within this strategy repertoire however, research point at the indispensability of deep-level strategies. Rather than surface-level or linear learning strategies (e.g., repeatedly rereading, coping texts, trying to memorize text literally), deep-level strategies (e.g., creation of summaries, maps) evoke the general capacity to analyze, structure, and organize knowledge which in turn promotes deep text processing and learning (Lahtinen et al., 1997; Nesbit & Adesope, 2006; Ponce & Mayer, 2014;

Schnotz, 2002). These strategies are also referred to as ‘generative’ strategies in educational research (Davies & Hult, 1997; Malmberg, Jarvenoja, & Jarvela, 2010; Ponce & Mayer, 2014), as they evoke active knowledge transformation by the creation of organizational or integrated relationships (Lee, Lim, & Grabowski, 2008; Lim, Lee, & Grabowski, 2009; Wittrock, 2010). Summarizing is such a deep-level generative study strategy (Friend, 2001; Westby, Culatta, Lawrence, & Hall-Kenyon, 2010).

Summarizing is regarded as an important strategy as it prompts essential learning strategies such as elaboration and organization, evoking higher levels of cognitive processing and better learning (Bangert-Drowns, Hurley, & Wilkinson, 2004; Weinstein & Mayer, 1986; Westby et al., 2010). Consequently, summary writing is also described in literature as a ‘writing-to-learn’ activity (Bangert-Drowns et al., 2004), as important learning strategies are executed during the phases of pre-writing (i.e., preparing the summary), construction (i.e., making the summary) and post-writing (i.e., evaluating and revising the summary) (Alamargot, Plane, Lambert, & Chesnet, 2010; Berninger, Fuller, & Whitaker, 1996; Flower & Hayes, 1981). Although a summary can take many forms (i.e., linear outlines, matrices, maps), it are especially summaries requiring graphical text reorganization that are found be beneficial in students’ text processing and learning (e.g., Nesbit & Adesope, 2006). Graphical summaries differ greatly from verbal linear summaries, as those often maintain the sequential structure of the text. In contrast, spatial summaries represent spatial and structural relations of components described by the text (Leopold, Sumfleth, & Leutner, 2013). In this dissertation, this kind of summary is referred to as a ‘graphical summary’. Schematizing or graphically summarizing implies the transformation of linear multi-paragraph text into a visually coherent and hierarchically organized spatial structure. A graphical summary can thus be regarded as an extensive and detailed elaborated form of graphic organizer (Stull & Mayer, 2007), wherein only the text’s main ideas or general structure is outlined. Figure 2 represents in this respect the difference between a linear summary, a graphic organizer, and a graphical summary.

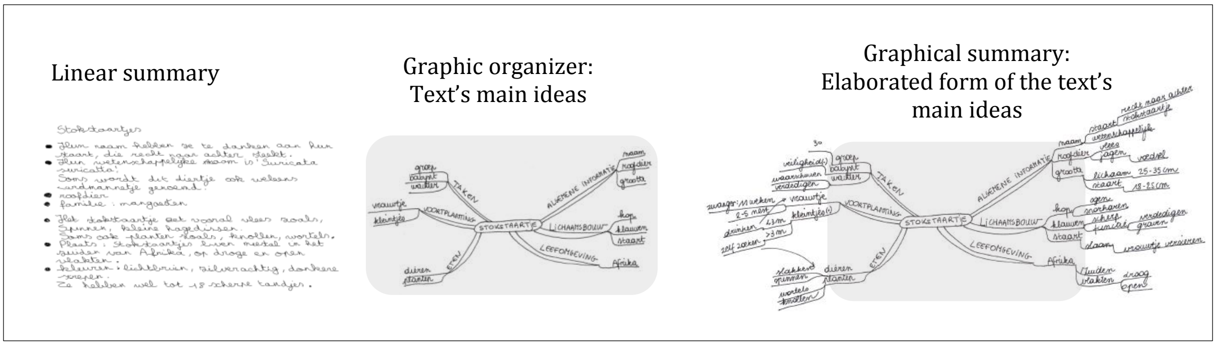

Figure 2. Visual illustration of the difference between a linear summary, a graphic organizer, and a graphical summary.

Research identified aspects to be included in either the summary’s graphical design or content, that can enhance text processing and learning. For example, beneficial effects have been demonstrated for the incorporation of gestalt principles (O’Donnell, Dansereau, & Hall, 2002;

Wallace, West, Ware, & Dansereau, 1998) and mental imagery (Anderson, & Hidde, 1971; Leopold et al., 2013) into graphical designs. Gestalt principles relate to the visual nearness of information by using similar colors and shapes ('equality') or the grouping of related elements by means of their spatial arrangement ('proximity') (Wallace et al., 1998). Furthermore, certain keywords can be complemented with a corresponding representation which enhances mental imagery processes (Anderson & Hidde, 1971; Leopold et al., 2013). Including gestalt principles and mental imagery have found to promote faster knowledge identification, processing, and retention (Anderson & Hidde, 1971; Nesbit & Adesope, 2006; O'Donnell et al., 2002; Wallace et al., 1998). Beside these design-related elements, also the way in which the graphical summary's content is rearranged might enhance text processing and learning. In this respect, informative texts are succinctly summarized by hierarchically associating super- and subordinate keywords or sentences to blanket terms (i.e., the main ideas of the text). Various studies underpin the manner of hierarchically associating keywords when learning from text (Nesbit & Adesope, 2006; Stull & Mayer, 2007; Hilbert & Renkl, 2008).

Learners struggling with strategic learning

In sum, a first consideration derived from theoretical and empirical research draws us at the importance of possessing a rich strategic repertoire to be able to effectively process and learn informative texts. This strategy repertoire should entail deep-level strategies such as graphical summarization as a powerful to-be-mastered strategy. Despite this importance, previous research indicated that students still do not consistently use effective learning strategies, do not possess the necessary tools to learn complex course material and experience study troubles attributed to failure in appropriate strategy access or selection (Bean, Singer, Sorter, & Frazee, 1986; Dembo & Eaton, 2000; Frazier, 1993; OECD, 2010, Rachal, Daigle, & Rachal, 2007). Furthermore, specifically related to summarization, many young students still turn to counterproductive methods to summarize information (i.e., copy-and-delete method, whereby text sentences are copied linearly) (Brown & Day, 1983; Friend, 2001). These findings brings us to the second consideration drawn from the above described theories and studies, that is the need for educational interventions to introduce learners in this this strategic learning.

Educational interventions should introduce learners in strategic learning

All abovementioned theories agree upon the fact that education plays a critical role in initiating students' self-regulated learning in general and students' text-based learning in particular. In this respect, they point at the fact that students often will not develop and use these strategies spontaneously and explicit inducement is required by means of instructional interventions (Alexander, 1998; Mayer, 1996; Pressley et al., 1987; Weinstein, Jung, et al., 2011).

The need for strategy initiation in early adolescence

The initiation of text-learning strategies becomes crucial in late elementary education. From then on, students have to spend more time on learning from informative texts, which will be the most commonly used text type during their future educational carrier (Bakken & Weddon, 2002; Rawson, 2000). However, many elementary school teachers generally stay focused on teaching basic reading strategies in narrative text and rarely provide instruction on how to approach informative (study) texts (Edmonds et al., 2009; Fang, 2008; Hall-Kenyon & Black, 2010; Jeong, Gaffney, & Choi, 2010;). This is problematic, as narrative texts differ greatly from informative texts, as they generally do not follow a typical story grammar or structure, contain more unfamiliar vocabulary, and can include a variety of relationships and text structures. Thus, processing and learning informative texts requires unique text-learning strategies, strategies that help students to organize, condense and retain text information (Hall-Kenyon & Black, 2010; McNamara, et al., 2007; Nesbit & Adesope, 2006; Vauras, Kinnunen, & Kuusela, 1994). This text-learning strategy use should be initiated in early adolescence for students to meet more complex study requirements (McNamara & Kintsch, 1996; Meneghetti et al., 2007). Review studies have specifically illustrated the beneficial effects of well-planned and well-instructed use of graphic organizers or maps in this respect (e.g., Dexter & Hughes, 2011; Kim, Vaughn, Wanzek, & Wei, 2004; Nesbit & Adesope, 2006; Vekiri, 2002). Instructional mapping techniques are also referred to in Alexander's Model of Domain Learning (1998) as means to help novice or acclimated learners in the context of learning from texts. They can help students grasp interrelated ideas within lessons, provide strategic guidance and opportunities for strategic reinforcement (Alexander, 1998). The present dissertation focusses on mind maps as particular type of graphic organizers which are used as graphical summaries incorporated into an educational intervention.

Mind maps: Definition and essential characteristics

Mind maps were formally introduced by Buzan (1974) as a 'powerful graphic technique which provides a universal key to unlocking the potential of the brain' (Buzan & Buzan, 1995, p. 59). Mind maps can be regarded as particular types of graphic organizers, described by Stull and Mayer (2007) as 'spatial arrangements of words (or word groups) intended to represent the conceptual organization of text' (Stull & Mayer, 2007, p. 810). Mind maps align with this general definition but differ greatly in their design and content arrangement from other types of graphic organizers, such as node-link maps (Blankenship & Dansereau, 2000), knowlegde maps (Katayama & Robinson, 2000), and concept maps (Novak, 2002). Figure 3 on the next page illustrates in this respect the difference between a mind map and a concept map.

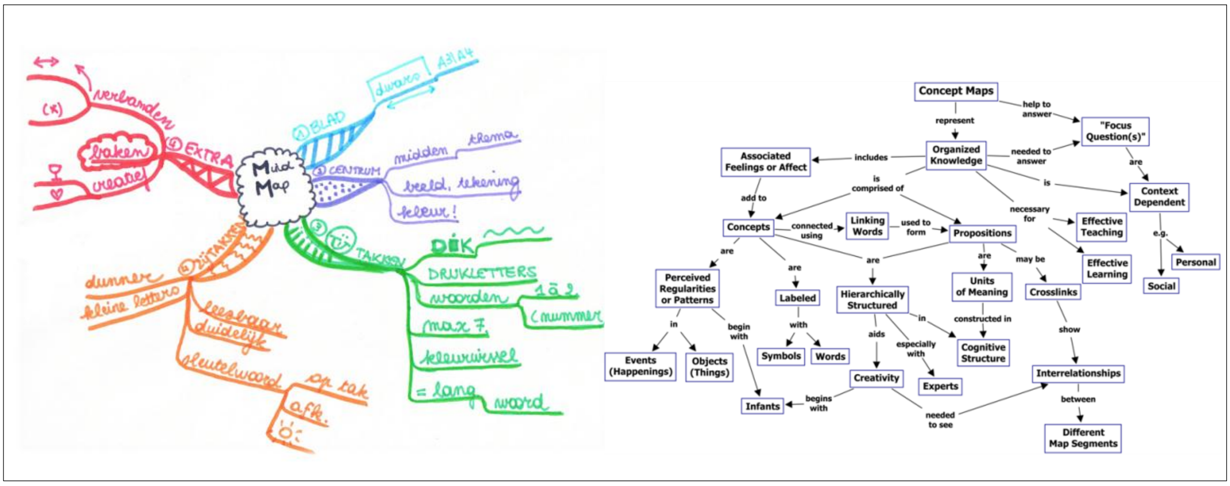

Figure 3. Difference between a mind map (on the left side) and a concept map (on the right side).

As to their graphical content or internal structure, linear text content is reorganized in a mind map by placing the text's central theme in the middle of the page, from which several related main text ideas radiate out in the shape of branches. Associated to these main branches, other sub-branches represent subordinate text ideas. In this way, a mind map reflects the macro structure of the text together with more precise relationships among related text units. A mind map generally includes no more than seven main branches. This number is based upon Miller's study (1956), pointing at the limitation of our working memory in processing no more than seven information units or 'chunks' simultaneously. Reducing large texts into smaller units, leads to better memory storage (Miller, 1956). Mind maps furthermore allow the representations of more complex text relationships (e.g., contrasts, causations, comparisons) by adding numbers, images, arrows, or connectors to the branches (Buzan, 2005).

As to a mind map's external appearance, various characteristics are incorporated based upon brain and educational research confirming the positive learning effects of using association (Budd, 2004; Haber, 1970; Mento, Martinelli, & Jones, 1999), mental imagery, colors (Anderson & Hidde, 1971), and gestalt principles (O'Donnell et al., 2002; Wallace et al., 1998). These characteristics were translated into a set of design-principles (based on Buzan, 2005):

1. Main branches, directly associated with the central topic, are thicker than sub-branches.
2. Capital letters are used on the main branches, small letters on the sub-branches.
3. A different color is used for every main branch and its associated sub-branches.
4. Connect images to keywords or replace keywords with images.
5. The map must be readable without turning the page.
6. Keywords must be placed on the branches.
7. The radial structure of the map should be carefully respected.

Following these design-principles is essential, as they reflect basic characteristics determining mind maps' effectiveness (Buzan, 2005). Therefore, mind maps should not be confused with other types of graphic organizer, such as the more familiar and extensively studied concept maps (Novak, 2002), which are hierarchically top-down oriented, rely less on specific design-principles (e.g., using colors or images), and require the explicit use of connective terms between concepts which are represented in boxes or circles (Budd 2004; Davies, 2011) (see Figure 3). Furthermore and unfortunately, among various mind map studies, researcher did not always respected the essential mind map characteristics (e.g., Brinkmann, 2003; Willis & Miertschin, 2006; Zipp, Maher, & D' Antoni, 2009), causing biased views on mind map's effectiveness and making direct comparison of different study effects impossible. To avoid this caveat, the above described design-principles were closely followed, ensuring identical mind maps application in each one of the mind map studies incorporated into this dissertation.

Theoretical underpinnings of working with maps

Next to the effectiveness of specific design and content characteristics, also several theoretical frameworks underpin how mind maps, as particular types of graphic organizers, might assist students in processing and learning from texts. These theories are extensively discussed in meta-analyses of Vekiri (2002) and Nesbit and Adesope (2006). The most important theories are briefly outlined underneath.

First, Paivio's (1991) *Dual Coding Theory* builds upon the way information is processed. Paivio suggests that two separate and independent systems exist in our memory for the processing and storage of information: a symbolic and sensorimotor system. Because of this, visual and verbal information are processed and stored separately and independently from each other. Visual representations may contribute to learning as information storage can occur in two ways. As this enables the learner to make associations between the visual and verbal material, information is easier remembered (Paivio, 1991, 2006). This line of reasoning is also endorsed by Robinson, Robinson and Katayama (1999), and Katayama and Robinson (2000).

A second important theory is the *Cognitive Load Theory* (Sweller & Chandler, 1994; Sweller , van Merriënboer & Paas, 1998). This theory builds upon the fact that people have a limited short-term memory and a very effective long term memory. Cognitive load on the short-term memory can be reduced by adding graphical representations to texts. Sweller and Chandler (1994) and Sweller and colleagues (1998) distinguish between extraneous, germane and intrinsic cognitive load. The two first types are caused by the way in which information is presented. Although germane load refers to the effort of constructing schemas (i.e., organized patterns of thought), extrinsic cognitive load can be overcome by better instructional designs. Intrinsic cognitive load is inherently related to the complexity of the information itself. Intrinsic cognitive load is hard to avoid, but can be decreased by reducing the complexity of the information (Sweller & Chandler, 1994; Sweller et al., 1998).

The *Visual Argument Hypothesis* (Waller, 1981) ascribes the advantages of graphical representations to the maps' spatial characteristics which communicate the complex text content more effectively. Because of this, processing the map requires less mental effort in working memory. In this respect, O'Donnell (1993) refers to the reduced amount of text in graphical representations. Because of this, learners can process the information more easily, and the difficulty of the text material is reduced. Furthermore, the organization of the information provides an anchor for idea recall afterwards. Especially students with lower verbal abilities might benefit from this, since the number of words and complex syntax is replaced by key words and interrelated ideas (DiCecco & Gleason, 2002; Lambiotte, Skaggs, & Dansereau, 1993; O'Donnell, 1993). Also Hall & Sidio-Hall (1994) and Robinson and Kiewra (1995) align with the Visual Argument Hypothesis.

Finally, the *Conjoint Retention Hypothesis* (CRH) (Kulhavy, Stock, Woodard, & Haygood, 1993; Kulhavy, Woodard, Haygood, & Web, 1993) is an interpretation and combination of the Dual Coding Theory and Visual Argument Hypothesis. Again, it is assumed that maps are encoded in memory as intact images, in which both the maps' individual characteristics as the relationships between characteristics are stored (cf. Visual Argument). By simultaneously studying a text and a corresponding map, two memory traces are created and linked to each other (cf. Dual Coding), and information is conjointly retained. When students try to remember text information, they can use information from the 'intact map image'. In other words, it is more likely that textual information will be remembered when the text and corresponding map are studied together (Kulhavy, Stock et al , 1993, Kulhavy, Woodard et al., 1993; Robinson & Molina, 2002). However, Griffin and Robinson (2005) did not always find support for this hypothesis.

Mind mapping as an organizational and as a meta-learning strategy

The above mentioned theoretical models regarding the effectiveness of graphic organizers, maps, and specific mind map characteristic give thus reasons to believe that mind maps might be effectively used into strategy instruction for stimulating particular text-learning strategies. In this respect, various meta-analysis have consistently confirmed the effectiveness of mapping methods as an organizational learning strategy to help students summarize and learn from texts (e.g., Dexter & Hughes 2011; Nesbit & Adesope 2006; Vekiri 2002). Research on writing and summarizing describes in this respect how students are engaged into important cognitive operations (e.g., deletion of unnecessary or trivial information, finding blanket terms) through the cyclical phases of pre-writing, construction and post-writing (Berninger et al., 1996; Flower & Hayes, 1981; Friend, 2001). Also, mind mapping was already studied as an organizational strategy to learn high school students schematically represent information (Zipp et al., 2009) or as a prompted study technique (Farrand, Hussain, & Hennessy, 2002). Thus, mind maps might be employed in classroom as an organizational strategy, to enhance students' graphical summarization skills.

However, some researchers also refer to the potential of maps for 'meta-learning', believing that maps might induce a larger strategy repertoire (Chmielewski & Dansereau, 1998; Chiou, 2008; Okebukola, 1992). This term was introduced by Biggs (1985) and further elaborated by Jackson (2004), referring to a strategy helping students learn how to learn meaningfully and independently. In this respect, using maps during instruction, might prompt spontaneously independent cognitive (e.g., Broer et al., 2002) and metacognitive text-learning strategy use (Hilbert & Renkl, 2008), while learners engage in the phases of forethought, performance and reflection (Pintrich, 2000). Being involved in mapping instruction, might thus provoke that students develop a top-down learning set of processing strategies that can facilitate learning from text (Chmielewski & Dansereau, 1998). Therefore, Watkins (2001) refers to meta-learning as an additional cycle in the learning process, as students are engaged in self-regulated learning through strategy instruction, and those acquired strategies are subsequently applied for future learning and transferred to other learning situations. Especially in view of the importance of inducing a large text-learning strategy repertoire in pre-adolescence, mapping instruction would thus be more acceptable and cost effective if it results in training students' ability to improve their learning (Chmielewski & Dansereau, 1998).

Figure 4 represents the relationship between mind mapping used as an organizational learning strategy (inner circle) and meta-learning strategy (outer circle) (based on Watkins, 2001). Renewing interest in the value of mapping as meta-learning strategy seems thus very worthwhile, especially as no studies to date have investigated mind mapping as a meta-learning strategy in late elementary education.

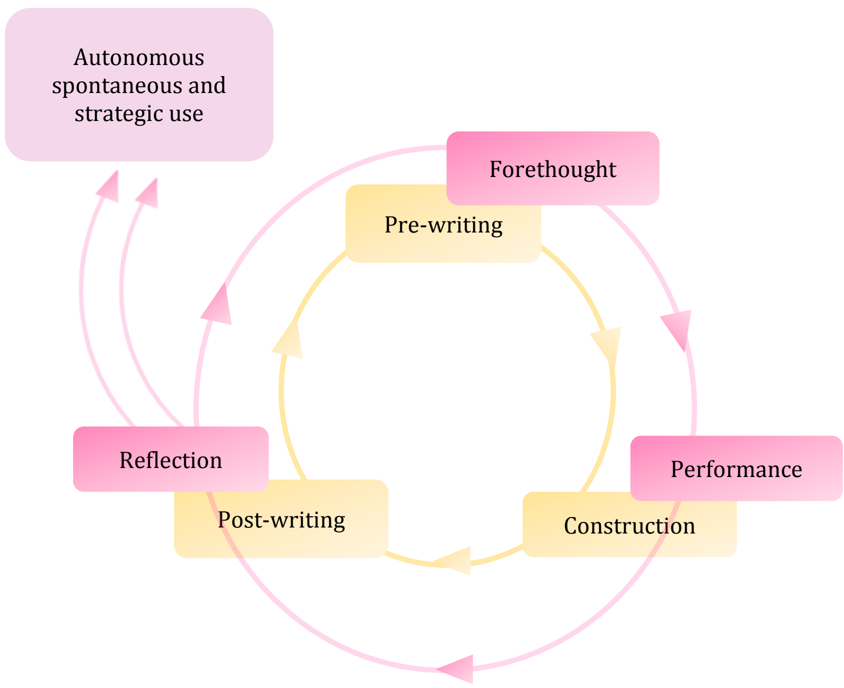

Figure 4. The relationship between mind mapping as an organizational strategy and as a meta-learning strategy.

Critical intervention components

Although mind map implementation in education is described in more popular publications (e.g., Buzan 2005; Hoffman, 2001) and mind maps are already regularly used in practice, literature on validated mind map strategy instructions is scarce. Therefore, critical intervention components were identified based on meta-analyses concerning self-regulated learning and learning strategy intervention research (Bangert-Drowns et al., 2004; Dignath & Büttner, 2008; Donker et al., 2014; Hattie, Biggs, & Purdie, 1996; Pressley, Graham, & Harris, 2006). The components are anchored to the questions 'What to teach?', 'Where to each?', 'How to teach?', and 'When to teach?' (Mayer, 1996) (Table 1).

What to teach? As opposed to the single ability view, wherein learning strategies are viewed as a single monolithic ability, strategies should be considered as a collection of smaller subcomponent skills. Instruction should therefore focus on relevant strategies for as well processing the information and strategies for controlling those processes (Mayer, 1996). Consequently, when aiming to induce learning-to-learn skills both cognitive and metacognitive strategies should be the focus of instruction (e.g., Askell-Williams, Lawson, & Skrzypiec, 2012; Bangert-Drowns et al., 2004; Simpson & Nist, 2000). For example, reflection prompts can be integrated into a cognitive strategy instruction, serving as a scaffold to students' reflections on their current knowledge and learning processes (Bangert-Drowns et al., 2004). Further, it is important to focus on both declarative (knowledge about strategies), procedural (knowledge on how to apply strategies), and conditional knowledge (knowledge on when to apply strategies) during instruction (Garner, 1990; Weinstein, Jung, et al., 2011). As to the incorporation of graphic organizers, Robinson (1998) additionally indicates graphic organizers should be applied that can be easily constructed by novices.

Where to teach? Educational research should be classroom-based and classroom-targeted (Boekaerts & Corno, 2005; Paris & Paris, 2001), therefore strategy instruction should occur within students' naturalistic school context. Cornford (2002) refers in this respect to two curriculum approaches to teach cognitive and metacognitive skills, that is the adjunct-approach (i.e., skills are taught as a separate subject in separate courses), and the metacurricular approach (i.e., strategies are taught in the context of specific subjects). Various researcher agree upon following this second, embedded approach, as strategy instruction should connect with students' domain-specific knowledge and transfer is more likely to occur (e.g., Cornford, 2002; Mayer, 1996; Veenman, 2011).

How to teach? Cognitive scientists favors a process view on teaching strategies, involving a focus on the process of how to use strategies (Mayer, 1996). In this respect, instruction should be tuned to the three cyclical phases of self-regulated learning (i.e., forethought, performance, reflection) and writing-to-learn research (i.e., pre-writing, construction, post-writing) (Bangert-Drowns, 2004; Zimmerman, 2002). To this end, teachers should apply modeling, explicit strategy instruction and provide students with repeated practice opportunities (Kistner et al., 2010; Paris & Paris, 2001). Additionally, as general activities such as 'planning' might rather be abstract to learners, Veenman (2011) advises to translate these general steps into concrete activities to be applied to the task at hand by means of concrete step-by-step action plans. These steps can be explained, modeled and practiced. Research also considered how instruction should be delivered, that is by the researcher of by the teacher. Despite the fact that higher training effects were found for researcher-delivered instructions (Dignath & Büttner, 2008), effective teacher-delivered instructions are most preferable, as teachers can serve as facilitators of students' accumulating self-regulatory knowledge and skills for a longer period. It is a prerequisite however that teachers can call upon a knowledge-base to influence students' learning and have (pedagogical) content knowledge about cognitive and metacognitive strategies for learning (Askell-Williams et al., 2012; Kiewra, 2002). Consequently, an extensive teacher training and the provision of instructional support to implement the program (i.e., providing them with usable tools) are important preconditions for successful teacher-delivered instructions (Dignath & Büttner, 2008).

A final consideration relates to *when to teach* these text-learning strategies. In this respect, and as discussed earlier, it is preferable to initiate these strategies in late elementary education, as an effective study method to learn from texts becomes crucial (McNamara & Kintsch, 1996; Meneghetti et al., 2007). Mayer (1996) states that novice students can learn high-level learning strategies even before they have completely mastered a subject area. Additionally, younger children might also be more receptive to interventions as they may not have yet developed counterproductive learning habits (Donker et al., 2014). As to the intervention period, instructions yield most powerful long-term effects when having are longer-term implementation (Bangert-Drowns et al., 2004; Pressley et al., 2006; Simpson & Nist, 2000).

Table 1

Overview of the critical intervention components for strategy instruction

What to teach?	• Combination of cognitive and metacognitive strategies • Declarative, procedural, and conditional strategy knowledge • Easily to be constructed graphic organizers
Where to teach?	• Classroom-based • Metacurricular approach
How to teach?	• Focus on product and process • Modeling, explicit strategy instruction, repeated practice opportunities • Applying concrete step-by-step plans • Teacher-delivered preceded by an extensive teacher training and supplemented with instructional support
When to teach?	• Preferably in late elementary education over a long-term

Concluding thoughts

In sum, there are promising indications that educational (mind map) interventions might induce strategic learning in general and graphical summarization skills in particular. This instruction in text-learning strategies is most effective when it is oriented towards and integrated in students' spontaneous study activities (Pressley & Harris, 2006). However, little is known about the occurrence and combination of different text-learning strategies in elementary education students, resulting in many unanswered questions: Do elementary school children already use specific text-learning strategies? How can they best be categorized and do students already combine them into certain ways? Furthermore, can these strategies subsequently be induced and stimulated by means of a mind map strategy instruction? To provide answers to these questions, the studies included into the present dissertation are organized according to two general research lines, which will be discussed in the next paragraphs.

Two research lines

Research line 1: Assessing and profiling text-learning strategy use in fifth and sixth grade

In literature, many attempts have been made to assess learning strategies with a variety of measurement instruments and methods diverging according to the goal, context, content, target group and level of specificity (Schellings, 2011; Scott, 2008). However, a specific instrument assessing the use of text-learning strategies (goal and content) while learning from informative texts (context and level of specificity) in late elementary education (target group) is missing. Four measurement methods are particularly relevant in the context of learning from texts.

First, *task-specific self-report measures* can be used (e.g., Paulhus & Vazire, 2007; Samuelstuen & Braten, 2007; Schellings & Van Hout-Wolters, 2011; van Hout-Wolters, 2009). Here, data are gathered after task execution, as students are asked to report on their strategy use after they have finished a specific learning task. Generally, students are asked to rate the degree to which they executed the mentioned learning activity on a Likert-scale.

Second, also the *examination of traces* can provide meaningful insights into students' strategy use. Traces are concrete indicators of bygone episodes of strategy use (e.g., organization and memorization) and strategic processing (Braten & Samuelstuen, 2007; Wolters, Benzon, & Arroyo-Giner, 2011; Zimmerman, 2011) and observable after task execution (e.g., text markings and scratch paper notes). Often, scoring rubrics are applied to investigate the quantity and the quality of the traces. Data from trace methods can be transformed into frequencies, time of engagement, or other quantifiable information (Wolters et al., 2011).

Also *think-aloud methodology* is a frequently applied method in text learning research (e.g., Fox, 2009; Greene, Robertson, & Croker Costa, 2011). Here, learners are asked to verbalize all their ongoing actions and thoughts while learning, directly revealing learners' text processing and learning activities (Scott, 2008). Learners' verbalizations are transcribed by the researcher into think-aloud protocols (TAP), which can be subsequently coded. Afterwards, the occurrence of the coded categories are used for analysis purposes.

A final - very recent - method for measurement and analysis of students' ongoing writing processes during learning from text, is the *analysis of pen movements* (e.g., Alamargot et al., 2010; van Hell, Kuks, Dekker, Borleffs, & Cohen-Schotanus, 2011). Students' pen movements are registered with a digital writing pen, which results in 'pencast' (i.e., playable movies of students' writing movements). Pencasts can be uploaded to the computer and analysed.

These measurement methods distinguish themselves as to whether data are gathered off-line (i.e., after task execution) or on-line (i.e., during task execution) and are related to either a process- or product-oriented view on assessment (Table 2). A combination of different measurement methods is preferable over a single instrument to profoundly gain insight into students' text-learning strategy use, for assessing the effects of a given intervention (Boekaerts & Corno, 2005), and this increases the chance of explaining why an intervention worked or failed (Pressley et al., 2006).

Table 2
Categorization of measurement methods according to the data gathering moment and view on assessment

Off-line measures - Product-oriented perspective	On-line measures - Process-oriented perspective
Self-reports	Think-aloud measures
Trace data	Pen movements

Research line 2: Fostering generative text-learning strategy use with a mind map strategy instruction

Above, critical intervention components have been described to develop an effective strategy instruction to foster text-learning strategies. However, various influencing factors might play a role in the effectiveness of the use of mind maps in graphical summarization and the transfer of a larger text-learning strategy repertoire to an independent learning task. In this dissertation, specific characteristics related to either the instructional approach or individual student characteristics are taken into account.

Instructional approach

A well-known discussion is going on about working with researcher-provided versus student-generated maps (Kirschner, Sweller, & Clark, 2006; Lee & Nelson, 2005; Stull & Mayer, 2007). On the one hand, there are researchers pleading for the incorporation of *student-generated maps* into a strategy instruction. Their argumentation is based upon the activity theory, which states that deep learning involves the engagement of learners in productive learning activities (Kirschner et al., 2006; Stull & Mayer, 2007). In this respect, 'learning by doing' induces generative processing (i.e., deeper cognitive processing of the material). On the other hand, those processes might also be inhibited by the extra cognitive demands the learners' activity might require (Stull & Mayer, 2007).

Researchers inspired by the cognitive load research (Sweller & Chandler, 1994) support the use of author- or *researcher-provided maps*. Letting students 'learn by viewing' by providing them worked-examples reduces the level of extraneous processing. Because of this, more cognitive capacity is available for generative processing. As the worked-examples of maps provide scaffolds for students strategic processing, researcher-provided maps would offer more opportunities to learn (Kirschner et al., 2006; Leopold et al., 2013; Stull & Mayer, 2007).

Previous research has largely focused on the performance of secondary and higher education students' learning while working with either provided or self-constructed maps (e.g., Stull & Mayer, 2007; Leopold et al., 2013). In these studies, students' map use was explicitly prompted, providing no insight in which instructional approach best promotes spontaneous independent strategy use. Therefore, this dissertation wants to explicitly compare both instructional approaches in promoting strategy transfer, i.e., the way in which the taught strategies are spontaneously applied by students during an independent learning task.

Student characteristics

Not all learners are alike in their need for instruction (Veenman, 2011) and various aptitude-by-treatment interactions (i.e., different groups of learners might benefit from different instructional approaches) might occur (Cronbach & Snow, 1969; Jonassen & Grabowski, 1993). Therefore, also particular student characteristics might influence an intervention's effectiveness.

A first potential influencing factor might be students' *grade* (Alexander, 1998; Anderman & Midgley, 1997). In this respect, sixth graders might already be more receptive to use more complex strategies (Alexander, 1998), such as graphical summarization, as they are already more acquainted with the cross-curricular 'learning to learn' attainment targets.

Also *gender* can be a characteristic of influence. Research on gender differences in organizational strategy use is rather limited and inconclusive (Rozendaal, Minnaert, & Boekaerts, 2003; Slotte, Lonka, & Lindblom-Ylänne, 2001), and there is little available research directly comparing the effects of gender on graphics (McTigue, 2009). However, strategy research did already identified gender-associated differences in students' cognitive and metacognitive strategy use (Askell-Williams et al., 2012; Slotte et al., 2001; OECD, 2010). For instance, Gerstner and Bogner (2009) found that girls tend to produce more complex (concept) maps, and Abdolahi et al. (2011) found that girls attain higher scores on a medical multiple-choice test after a mind map lesson.

Third, a strategy instruction's effectiveness might differ among students with different ability or *achievement levels* (Donker et al., 2014; Hattie et al., 1996, Mason, Meadan-Kaplansky, Hedin, & Taft, 2013). High achievers are found to be more effective and flexible in their strategy use (Fox, 2009; Vauras et al., 1994). In contrast, Hattie et al. (1996) reported that low- and high-ability students might benefit the least from strategy instruction. Especially low achievers might show large deficits of cognition, metacognition and motivation (Pressley, 1995).

A fourth possible influencing student characteristic is students' *home language*, since students with lower proficiency in the instructional language might experience more difficulty with graphical summarization (Nesbit & Adesope, 2006). On the other hand, students with lower verbal proficiency might profit more from worked-examples as they provides scaffolds to their cognitive processing (O'Donnell et al., 2002).

Finally, it also important to be considered factor is students' *learner profile*. In this respect, it might be that (concept) mapping strategies, as generative strategies, do not work equally well for students with different styles of cognitive processing (Grabowski, 2003).

Research lines and sub goals

Two important lines of research are delineated from the above described framework, which will be the focus on in this dissertation.

(1) A first research line focusses on the *assessment and profiling of text-learning strategy use during learning from text in late elementary grades*, stemming from the lack of appropriate measurement instruments to assess text-learning strategies in late elementary grade and the need for data triangulation in this respect. By means of these measurement instruments it is furthermore aimed to profile learning from text in pre-adolescence and to provide insights into text-learning strategies, including graphical summarization skills, already used in elementary grades and their strategic combination.

(2) A second research line focusses on *fostering text-learning strategies by means of a mind map strategy instruction*, building on the promising role of using graphic organizers such as mind maps to stimulate text-based learning. This line of research is subdivided into two sub goals.

- *Sub goal 1*. First, it is aimed to investigate mind mapping as an organizational strategy. Graphical summarization can be regarded as one particular (organizational) text-learning strategy. In this respect, it is aimed to develop a mind map strategy instruction to stimulate students' graphical summarization skills.
- *Sub goal 2*. Second, it is aimed to investigate mind mapping as an meta-learning strategy, investigating how mind mapping can be used to initiate a larger text-learning strategy repertoire.

Within these specified sub goals, the following class- and student level characteristics are explicitly taken into account:

The role of the *instructional approach* at class-level. In this respect, it is investigated whether different effects are found when implementing either researcher-provided or student-generated mind maps into the strategy instruction.

The role of *student characteristics* at student-level. In this respect, gender, grade, home language, achievement level and learner profile are studied.

Design of the studies and overview of the dissertation

The studies entailed in this dissertation can be typified as descriptive and quasi-experimental research. Descriptive studies use methods to describe and interpret what exists in the present, whereas quasi-experimental studies investigate intervention effects in naturally constituted classes assigned to either an experimental or a control condition (Koul, 2009). The included studies largely represent quantitative research, whereby quantifiable data is collected that is statistically analyzed in an objective manner (Creswell, 2008). However, also qualitative research is explored and employed, whereby data are collected which consist of participants' words (Creswell, 2008). Here, data transformation is applied, whereby qualitative data (e.g., transcripts or think aloud protocols) are converted into numerical scores which can be analyzed statistically (Tashakkori & Teddlie, 2010).

To increase research validity, each of the studies described in this dissertation is characterized by methodological triangulation (Denzin, 2009). More specifically, between-method methodological triangulation is applied, wherein contrasting research methods are used to investigate a research issue. More particularly, the research questions proposed in the different empirical studies are answered by differently combining the analysis of self-reports, think-aloud protocols, traces and pen movements.

This dissertation entails 10 chapters wherein, besides an introductory chapter (chapter 1) and concluding chapter (chapter 10), eight chapters are included (chapter 2 to 9). Each of these eight chapters documents on a different empirical study and is based on a published or submitted article in an international peer reviewed journal or in journals listed in the Social Science Citation Index. Table 3 provides an overview of the research lines, chapters, research goals, research design and sample, data collection and triangulation, and data-analysis techniques for the different studies. Figure 5 visualizes the structure of this dissertation and positions the studies within the research lines (RL). Chapter 2, 3, and 4 fit in with the first research line 'Assessing and profiling text-learning strategy use' and chapter 5 to 9 fit in with the second research line 'Fostering text-learning strategies by means of a mind map strategy instruction'. Figure 5 clarifies the underlying relationships between the different chapters.

Chapter 1 is the general introduction of the present dissertation, wherein the theoretical framework is outlined. More particularly, the importance of stimulating text-learning strategies in general and graphical summarization skills in particular in late elementary grades is discussed. Based on this, two important research lines are delineated and described in detail. Furthermore, a detailed overview of the design and studies included in the dissertation is provided.

Chapter 2, *Development of the Text-Learning Strategies Inventory: Assessing and profiling learning from texts in fifth and sixth grade*, focusses on the off-line measurement of text-learning strategies by means of a task-specific self-report inventory. This chapter first reports on the development of the 'Text-Learning Strategies Inventory' (TLSI). This instrument consists of a specific learning task (i.e., studying an informative text) and an inventory querying students about their applied text-learning strategies. The TLSI was administered at the beginning of 2011 to 896 students (sample 1) and in September 2011 to 644 students (sample 2). To validate the instrument, parallel analysis and an explorative factor analysis were conducted on the first sample, and a confirmatory factor analysis was conducted on the second sample. Also measurement invariances across gender was examined. Second, the existence of learner profiles (i.e., the combination of text-learning strategies in a certain way) was explored by means of hierarchical (sample 1) and k-means (sample 2) cluster analyses. One-way analysis of variance and chi-square analysis were conducted to furthermore investigate the relationship between learner profile and text recall, and between learner profile and gender. This chapter is published in the *Journal of Psychoeducational Assessment*.

Chapter 3, *Using on-line and off-line measures to explore fifth and sixth graders' text-learning strategies and schematizing skills,* explores students' text-learning strategies from a different methodological perspective. Specifically, text-learning strategies in general and graphical summarization skills in particular are measured off-line (i.e., after task-execution, by means of trace methodology) and on-line (i.e., during task-execution, by means of think-aloud protocol analysis and pen movement analysis). To this aim, a qualitative study with 20 late elementary students from four different classes was set up at the beginning of 2011. The same learning task as in chapter 2 was used, yet the administration differed as students were tested individually and asked to think aloud. In view of future analyses, also the TLSI was administered (see chapter 4). Further, a graphical summarization task was administered, wherein students graphically summarized an informative text paragraph with a digital writing pen. Descriptive analyses were conducted to provide insight into students' text-learning strategies and to explore students' strategy repertoire. One-way analyses of variances were used to explore achievement-level differences in text-learning strategy use and schematizing skills. This chapter is published in *Learning and Individual Differences*.

Chapter 4, *Learning from text in late elementary education. Comparing think-aloud protocols with self-reports*, is a shorter chapter investigating the correspondence between two data gathering methods (i.e., off-line self-reports and on-line think-aloud protocols) to assess text-learning strategy use. To this aim, the think-aloud data, explored in chapter 3, were complemented with students' self-report data and correlational analysis was used to investigate their correspondence. This chapter is published in the *Procedia of Social and Behavioral Sciences*.

From chapter 5 on, studies are represented which fit in with the second research line. Chapter 5, *Schematizing and processing informational texts with mind maps in fifth and sixth grade*, is a pilot-study, exploring the appropriateness of implementing mind mapping in fifth and sixth grade. To this aim, a repeated measures design (pretest, intermediate test, and posttest) was used involving 62 students from 4 different classes. A ten-week researcher-delivered instructional mind map intervention was implemented to investigate students' application of the mind map rules and processing of textual information. During the intervention, students gradually learned how to construct a mind map from an informative text. Findings obtained in this study demonstrate that mind map instruction can already be used in late elementary grades.

Furthermore, the developed strategy instruction can be used as a baseline in further large-scale research to develop teacher-delivered mind map strategy instruction programs. This chapter is published in the *Middle Grades Research Journal*.

Chapters 6 to 9 represent four chapters documenting on the effects of a large-scale intervention study. Two experimental conditions working with either researcher-provided (n=213) or student-generated (n=219) mind maps and one control condition (n=212) were involved in a repeated measures design (pretest, posttest and retention test). Pretest data were collected mid-September 2011. Experimental condition teachers received a 1.5-hour after-school training prior to the intervention period and implemented one mind map lesson (50 min) per week over a time span of 10 weeks (from the end of September 2011 to mid-December 2011). Control condition teachers followed their regular teaching repertoire. The posttest and retention test were administered at the end of December 2011 and mid-March 2012 respectively. During test administration, all students completed a learning task, the Text-Learning Strategies Inventory, a recall test, and a graphical summarization task.

Chapter 6 and 7 build upon the first sub goal within the second research line, investigating mind mapping as an organizational learning strategy to stimulate students' graphical summarization skills. First, chapter 6, *Stimulating graphical summarization in late elementary education: The relationship between two instructional mind map approaches and student characteristics,* focusses on students' graphical summarization skills as reflected in the graphical summarization task. Trace methodology was applied on students' informative texts and graphical summaries. Multilevel piecewise growth analysis was used to examine students' growth from pre- to posttest and from post- to retention test. Also the relationship with class-level (i.e., instructional approach) and student-level characteristics (i.e., gender, grade, home level, achievement level) is explored. This chapter has been accepted for publication in the *Elementary School Journal*.

Chapter 7, *From text to graphical summary: A product- and process-oriented assessment to explore the evolution in fifth and sixth graders' dynamic construction*, represents a sub-study of chapter 6. In this study, the graphical summarization product and process of 18 students (n_{exp1}= 5, n_{exp2}= 8, $n_{control}$= 5), involved in the large-scale intervention study, was investigated in detail. More particularly, those students were asked to complete the graphical summarization task with a digital writing pen, registering students' ongoing summarization processes. Both product-oriented (quality of the informative text traces, design and content) and process-oriented data (duration of writing periods) was analyzed by means of one way repeated measures analysis of variance. Furthermore, by means of a qualitative study, the existence of elaboration approaches and construction steps was investigated. One-way analysis of variance, correlational and chi-square analysis were used to investigate the relationship between the elaboration approaches, construction steps, product quality and instructional method. The manuscript of this chapter has been submitted to the *Journal of Literacy Research*.

Chapter 8 and 9 build upon the second sub goal within the second research line, investigating mind mapping as a meta-learning strategy. Chapter 8, *Mind mapping as a meta-learning strategy:*

Stimulating pre-adolescents' text-learning strategies and performance?, investigates the effects of the large-scale intervention study on students' spontaneously applied cognitive and metacognitive text-learning strategies during the learning task and students' text recall afterwards. The growth in students' self-reported (as reflected in the TLSI), and traced strategy use and in their recall performance was examined from pre- to posttest and from post- to retention test by means of multilevel piecewise growth analysis. Also the influence of the instructional approach (i.e., working with researcher-provided or student-generated mind maps) was studied. This study furthermore includes a general discussion on school based intervention research. This chapter has been resubmitted to *Instructional Science* (after a first revision based on the reviewers' comments).

Chapter 9, *Spontaneous mind map use and learning from texts: The role of instruction and student characteristics,* represents a sub-study of chapter 8. Here, it is investigated more in-depth whether class-level (i.e., instructional approach) and student-level characteristics (i.e., gender, mind map appreciation and mind map self-efficacy) affect students' spontaneous mind map use during text learning and whether this positively influenced their text recall. To this aim, chi-square and independent samples t-test were conducted on data from students who did and did not spontaneously used mind maps during the learning task. This chapter is published in the *Procedia of Social and Behavioral Sciences*.

Chapter 10 is the general discussion on the presented studies in the dissertation related to the proposed research lines. In addition, analyses are reported to investigate the influence of student-level characteristics (i.e., gender, grade, home language, achievement level and, learner profile) on the dependent variables included in chapter 8. Further, also limitations and future research aspirations are proposed. This chapter concludes with contributions and implications for research, practice, and policy.

Table 3

Research lines, chapters, research goals, research design and sample, data-collection and triangulation, and data-analysis techniques

	Chapter	Research goal	Research design and sample	Data collection and triangulation	Data-analysis techniques
	1	General introduction (theoretical framework, research lines, research design and overview of the dissertation)			
Research line 1	2	To develop and validate a self-report inventory to assess students' text-learning strategies; To explore the existence of different leaner profiles; To explore the relationship between learner profile and free text recall and between learner profile and gender	Cross-sectional survey ($n_{\text{sample 1}}$= 896, $n_{\text{sample 2}}$=644)	Self-report method	EFA (SPSS, R, Lavaan packages) CFA (R, Lavaan packages) Cluster analysis (SPSS)
	3	To assess students text-learning strategies and schematizing skills; To explore achievement level-differences in text-learning strategies and schematizing skills; To explore different strategy repertoires	Cross-sectional design (n=20)	Think-aloud methodology Trace methodology Pen movements analysis	Descriptive analysis (SPSS) One-way analysis of variance (SPSS) Chi-square analysis (SPSS)
	4	To explore the correspondence between students' self-reported text-learning strategies and students' text-learning strategies as reflected in their think-aloud protocols	Cross-sectional design (n=20)	Self-report method Trace methodology	Correlational analysis (SPSS)
Research line 2	5	To explore the impact of a mind map intervention on students' application of mind map rules and processing of textual information (pilot study)	Repeated-measures design (n=62)	Trace methodology	One-way repeated measures analysis of variances (SPSS)
	6	To evaluate the impact of mind mapping as an organizational strategy; To investigate the impact of two instructional approaches and student characteristics	Quasi-experimental repeated measures design Two experimental ($n_{\text{exp.1}}$= 213, $n_{\text{exp.2}}$= 219) and one control condition(n=212)	Trace methodology	Multilevel piecewise growth analysis (MLwiN)
	7	To evaluate the impact of two instructional mind map strategy instruction on students' graphical summary products and ongoing summarization processes; To provide an in-depth exploration of students' construction phases	Quasi-experimental repeated measures design Two experimental ($n_{\text{exp.1}}$= 5, $n_{\text{exp.2}}$= 8) and one control condition (n=5)	Trace methodology Pen movement analysis	One-way repeated measures analysis of variances (SPSS) One-way analysis of variance (SPSS) Correlational analysis (SPSS) Chi-square analysis (SPSS)
	8	To evaluate the impact of mind mapping as an meta-learning strategy; To investigate the impact of two instructional approaches and student characteristics	Quasi-experimental repeated measures design Two experimental ($n_{\text{exp.1}}$= 213, $n_{\text{exp.2}}$= 219) and one control condition(n= 212)	Self-report method Trace methodology	Multilevel piecewise growth analysis (MLwiN)
	9	To evaluate the impact of two instructional approaches of mapping on students' spontaneous mind map use in relationship with their text recall and student characteristics (i.e., gender, mind map appreciation, mind map self-efficacy)	Quasi-experimental repeated measures design Two experimental ($n_{\text{exp.1}}$= 213, $n_{\text{exp.2}}$= 219) and one control condition(n= 212)	Self-report method Trace methodology	Chi-square analysis (SPSS) Independent sample t-tests (SPSS) One-way repeated measures analysis of variances(SPSS)
	10	General conclusion and discussion (overview and discussion of the main results, limitations and suggestions for future research, implications of the dissertation)			

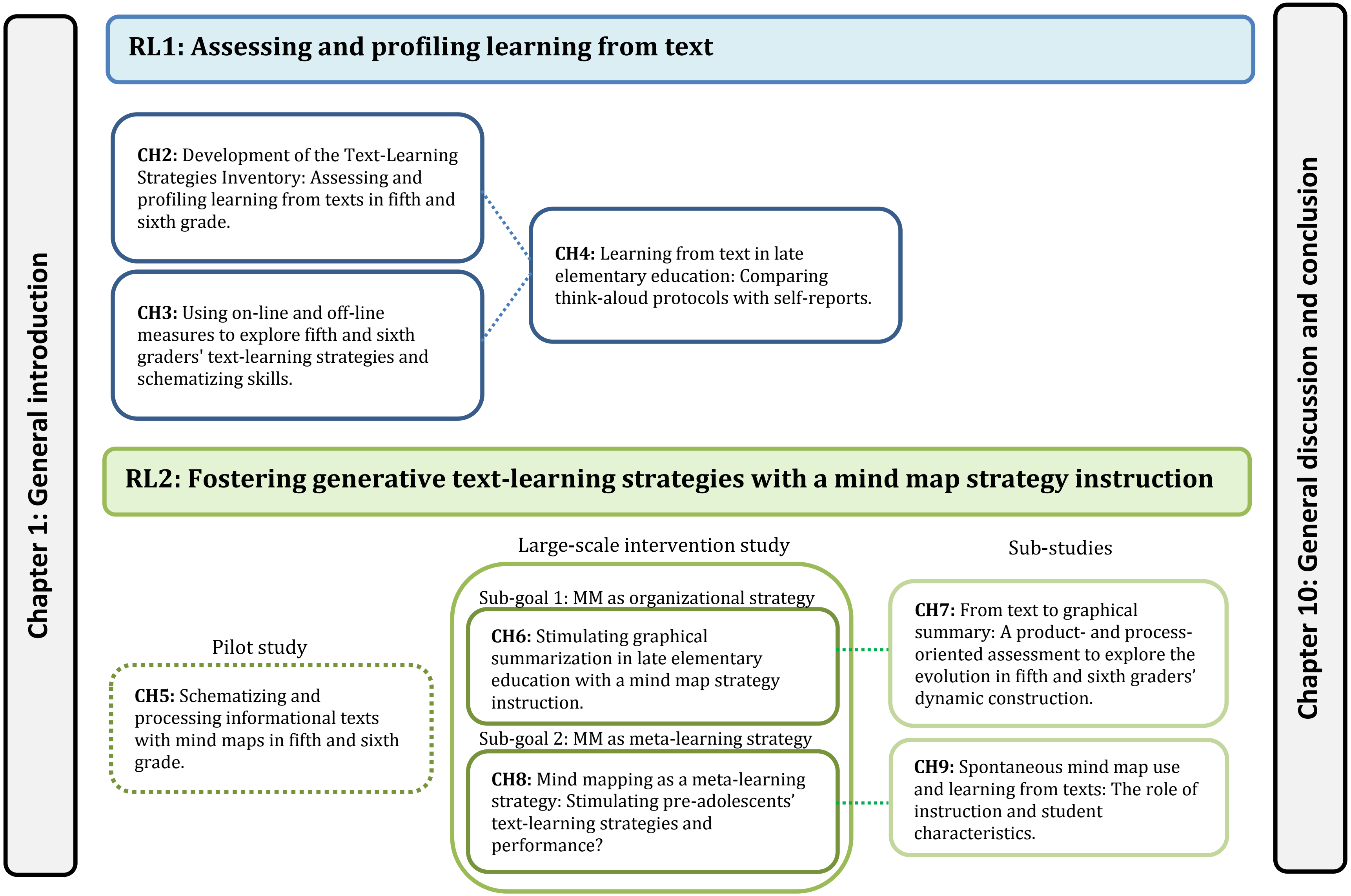

Figure 5. Overview of the studies and their relation to the general research lines and dissertation chapters.
Note. RL = research line.

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2 Development of the Text-Learning Strategies Inventory: Assessing and profiling learning from texts in fifth and sixth grade

This chapter is based on:

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Chapter 2
Development of the Text-Learning Strategies Inventory: Assessing and profiling learning from texts in fifth and sixth grade

Abstract

Independently learning from informative texts becomes increasingly important from the age of 11. Little information is available, however, on (a) how and to what extent late elementary education students already apply specific text-learning strategies, and (b) whether different learner profiles can already be distinguished. In this study, a 37-item Text-Learning Strategies Inventory (TLSI) was developed and validated by means of exploratory (Sample 1; 896 students) and confirmatory factor analysis (Sample 2; 644 students). The TLSI contains nine subscales reflecting overt, covert, surface- and deep-level cognitive and metacognitive text-learning strategies. Based on these subscales, four learner profiles (i.e., integrated strategy users, information organizers, mental learners, and memorizers) were identified and validated by means of hierarchical and k-means cluster analysis and study traces. No differences in text free recall score between profiles were found. More girls were profiled as integrated strategy users, whereas more boys were identified as mental learners or memorizers.

Introduction

Around the age of 11, students spend more time than previously on independently processing and learning new content from textbooks, which are increasingly used in classrooms to reach instructional objectives (Hall-Kenyon & Black, 2010). These informational study texts differ in many aspects from narrative texts as they do not usually follow a typical story grammar or structure, contain more unfamiliar vocabulary, and can include a variety of relationships and text structures (Hall-Kenyon & Black, 2010; Jeong, Gaffney, & Choi, 2010). Therefore, the need arises in late elementary education to provide specific instruction in approaching informative (study) texts. This instruction in text-learning strategies (i.e., strategies to select, organize, condense, and retain text information in a more memorable form) is most effective when it is oriented toward and integrated in students' spontaneous study activities (Pressley & Harris, 2006). Unfortunately, little large-scale information is available on spontaneously applied text-learning strategies of late elementary school students. In the present study, therefore, it is intended to fill this gap by developing a self-report inventory that allows the assessment and profiling of these text-learning strategies.

Strategy use during learning from texts

Theoretical models and general characteristics of text-learning strategies

In general, the use of learning strategies is a key component in various theoretical models of self-regulated learning (e.g., Pintrich, 2004; Zimmerman & Schunk, 2011). Moreover, models focusing specifically on learning strategies have also been developed. Examples are the Good Strategy User (GSU) model (Pressley, Borkowski, & Schneider, 1987), the Model of Strategic Learning (Weinstein, Jung, & Acee, 2011), and the Model of Domain Learning (Alexander, Murphy, Woods, Duhon, & Parker, 1997). Regardless of the theoretical models in which they are situated, learning strategies are believed to be procedural, purposeful, effortful, willful, essential, and facilitative and can be placed on a continuum from general through more domain- and task-specific (Alexander, Graham, & Harris, 1998). In strategy research focusing specifically on learning from texts, the concepts of text processing strategies, strategic processing strategies, and study strategies are used interchangeably referring to procedural activities supporting and guiding students' active manipulation of texts (Broekkamp & Van Hout-Wolters, 2007; Meneghetti, De Beni, & Cornoldi, 2007). In the present study, text-learning strategies refer to task-specific strategies students use for selecting, organizing, integrating, and recalling the subject matter of texts.

Text-learning strategy categorizations and learner profiles

In the literature, text-learning strategies have been conceptualized and categorized in various ways. One categorization is based upon the nature of the learning strategy, differentiating cognitive (e.g., organization, elaboration), metacognitive (e.g., monitoring), and motivational (e.g., self-efficacy beliefs) strategies (Pintrich, 2004; Weinstein & Jung, 2011). Second, text-learning strategies are categorized according to the level or depth of strategy use. Surface-level strategies encompass reproductive strategies, primarily aimed at basic memorization or rote learning (e.g., repeatedly reading or copying texts), whereas deep-level or generative strategies reflect the transformation or application of information and results in meaningful learning (e.g., summarizing, creating diagrams; Ausubel, 1968; Lahtinen, Lonka, & Lindblom-Ylänne, 1997). A third categorization refers to the perceptibility of the strategies. In this respect, overt (i.e., text-noting tactics producing physical records like highlighting or summarizing) or covert (i.e., non-observable internal mental-learning processes, such as reading or mental rehearsal) text-learning strategies can be used (Kardash & Amlund, 1991; Lahtinen et al., 1997; Wade, Trathen, & Schraw, 1990). Next to the categorization of text-learning strategies according to their nature, level or depth, or perceptibility, researchers have also explored the existence of different learner profiles, that is, approaches in which students combine text-learning strategies in a certain way (Abar & Loken, 2010; Wade et al., 1990).

Research on strategy use

The use and combination of learning strategies have been investigated in different task contexts and subject domains (e.g., science, mathematics) at various educational levels (e.g., Broekkamp & Van Hout-Wolters, 2007; Lahtinen et al., 1997; Lee, Lan, Hamman, & Hendricks, 2008). In these studies, performance measures such as recall tests are frequently applied to relate effective strategy use to increased performance in relation to learner characteristics such as gender (Fox, 2009; Liu, 2009; Slotte, Lonka, & Lindblom-Ylänne, 2001). However, especially researchers focusing on secondary and higher education documented on the abovementioned learning strategy categorizations, learner profiles, and associations between strategy use recall performance and gender. Little is known about the occurrence and combination of text-learning strategies in elementary education, largely due to the lack of measurement instruments for assessing text-learning strategies in elementary school. Therefore, an appropriate measurement instrument is needed.

Measuring text-learning strategies

Three important considerations were decisive in designing a task-specific self-report instrument preceded by a learning task, described below (Braten & Samuelstuen, 2004; Schellings, 2011). First, task-specific instruments acknowledge the context- and domain-specificity of text-learning strategies, as students adjust their strategic processing and learning to fit different tasks and purposes (Braten & Samuelstuen, 2004, 2007). Second, engagement in an authentic learning task overcomes the difficulty that elementary students might have with reflecting upon hypothetical learning situations. Third, in addition to the straightforward data gathering and scoring in large samples, self-report inventories involve less intrusion into students' normal thinking than on-line methods (e.g., think-aloud protocols; Caldwell & Leslie, 2010).

However, self-report measures are also associated with some concerns. First, students' memory reconstruction problems might affect answer accuracy (e.g., forgetting or being unaware of applied strategies; Veenman, 2011). Furthermore, inventory questions can serve as prompts distorting retrospective self-report (e.g., mentioning activities that did not take place; Veenman, 2011). Second, unintelligible items can hinder accurate inventory completion (Scott, 2008). Finally, the self-report nature of the inventory means that it documents students' perceptions and beliefs about their strategy use during text learning rather than actual strategy use (Braten & Samuelstuen, 2007). Researchers must consciously take into account these concerns when developing self-report measures.

Objectives of the study

The aim of the present study is twofold:

1. to develop a task-specific self-report inventory measuring late elementary school students' text-learning strategies, and
2. to explore and validate learner profiles and investigate their relationship with students' recall performance and gender.

Method

Participants

This study involves two independent samples, each comprising the students from randomly selected classes in Flanders (the Dutch-speaking part of Belgium). The first sample consisted of 896 students (49% fifth graders, 51% sixth graders; 49.3% boys, 50.7% girls; 9.3% non-native speakers of the instructional language of instruction), from 45 classes. Students' mean age was 11.86 years (*SD* = 0.73). The second sample consisted of 644 students (45.5% fifth, 54.5% sixth graders; 53.9% boys, 46.1% girls; 5.4% non-native speakers) from 35 classes. Students' mean age was 11.44 years (*SD* = 0.69).

Instruments

To meet the first research goal, the task-specific instrument Text-Learning Strategies Inventory (TLSI), consisting of a learning task and self-report inventory, was developed.

Learning task

First, a 491-word informative text about seahorses was written. It consisted of six topics: general information, body parts, environment, eating habits, reproduction, and protected species. Before the text was given to students, text readability and level of difficulty were evaluated by an expert on text learning and reading comprehension, a teacher, and an elementary school student. Students were given 30 min to study the text, as the intention of learning from texts is not only to achieve a high learning level but also to regulate study as efficiently as possible within a certain time span (Leopold & Leutner, 2012).

Development of the inventory

Tailored to this learning task, the task-specific self-report inventory was developed. It was opted to create a new instrument as previously published instruments mainly focused on secondary and high school students (e.g., Biggs, 1987; Braten & Samuelstuen, 2004; Entwistle & McCune, 2004; Pintrich, Smith, Garcia, & McKeachie, 1991; Schellings, 2011; Schmeck, Geisler-Brenstein, & Cercy, 1991; Weinstein & Palmer, 2002) or document on a more general portrait of self-regulated learning (Liu, 2009; Vandevelde, Van Keer, & Rosseel, 2013). Three main steps were undertaken in the development process, following guidelines on effective test development (Downing, 2006) and the development of task-specific self-reports (Braten & Samuelstuen, 2007). First, a large item pool was derived from an extensive literature review on previously published strategy measurements. Relevant questionnaire items were selected, adjusted, and reformulated in the past tense to refer to the accomplished learning task (Braten & Samuelstuen, 2007) and to reflect the different text-learning strategy categorizations described in the theoretical framework above. Second, to ensure content validity, the instrument was presented to five experts on self-regulated learning, text-based learning, and reading comprehension and to three elementary school teachers. Third, the inventory was pilot-tested in one fifth- (n = 17) and one sixth-grade (n = 18) class, to explore whether the items covered the elicited strategies and to avoid construct-irrelevant variance (e.g., incomprehensible items; Messick, 1995; Schellings, 2011). The final inventory consisted of 66 items, to be answered on a 5-point Likert-type scale, ranging from “I completely agree” to “I completely disagree.”

Prior knowledge and free recall test

To assure that there was no large variation in students’ prior knowledge that might influence text learning (Armand, 2001; Dochy, Segers, & Buehl, 1999), and to assess TLS with minimal intrusion into students’ subsequent learning behavior, students were first asked to write down everything they already knew about the text topic. A total percentage of prior knowledge was calculated by matching students’ prior knowledge to the text content. Furthermore, students’ free text recall was tested after learning by letting them write down everything they remembered from the text. The free recall score represents the percentage of correctly recalled text information.

Procedure

In both samples, the TLSI was administered during a class period of 75 min in the presence of a researcher and the classroom teacher. First, the prior knowledge test was administered. This revealed little or no prior knowledge (M = 1.05, SD = 0.78). Second, students were instructed to study the text in the way they would prepare for a test and were informed on the recall test afterward (Schellings, 2011). Students were allowed, but not obligated, to use scratch paper.

After 30 min, papers were collected and students completed the TLSI at their own pace, after which the free recall test was administered.

Data analysis

Explorative factor analysis (EFA; Sample 1)

As a first step in the EFA, a parallel analysis was conducted in R 2.14 to determine the number of factors to retain, with the 95th percentile as the comparison baseline and a number of random data sets of 1,000 (Hayton, Allen, & Scarpello, 2004). Next, EFA using maximum-likelihood extraction with promax rotation was conducted in SPSS 18, specifying a fixed number of factors to extract based on the parallel analysis.

Confirmatory factor analysis (CFA; Sample 2)

CFA was conducted, using the lavaan package 0.4-9 (Rosseel, 2012), to examine the stability of the exploratory structure and the model fit (Schmitt, 2011). As data were not normally distributed, with skewness values ranging from −1.30 to 1.22 and kurtosis values ranging from −1.82 to 2.97, the Yuan–Bentler (YB) scaled χ^2-test statistic was used (Yuan & Bentler, 2000). The use of cut-off values are not without controversy (e.g., Fan & Sivo, 2005). Therefore, we judged a combination of several fit indices to evaluate the model fit. For the root mean square error of approximation (RMSEA), a cut-off value close to .06 indicates a good model fit. Cut-off values lower than .08 are required for the standardized root mean square residual (SRMR; Hu & Bentler, 1999). A reasonable to good fit for the comparative fit index (CFI) and Tucker–Lewis index (TLI) is indicated by values above .90 or .95 (Schreiber, Nora, Stage, Barlow, & King, 2006). Furthermore, measurement invariance tests were conducted to verify factor structure invariance across gender (Cheung & Rensvold, 2002). For each subscale, model-based internal consistency was computed (Bentler, 2009).

Cluster analysis (Sample 1 and 2)

The presence of different learner profiles was explored in the first sample using a hierarchical cluster analysis in SPSS 18, with TLSI subscale scores as cluster variables. For minimizing within-cluster differences, Ward's method was used with the squared Euclidean distance as a similarity measure (Hair, Anderson, Tatham, & Black, 1998; Henry, Tolan, & Gorman-Smith, 2005). As scale measurements were comparable for all variables, data were not standardized. To validate the number of clusters, k-means cluster analysis was conducted on the second sample. In addition, markings in the informative texts and annotations on the scratch paper were coded with 0 (no highlighting, no scratch paper noting) or 1 (highlighted text, scratch paper use) to verify with chi-square analyses the relationship between learner profile and study traces.

One-way analyses of variance and chi-square analysis

One-way analyses of variance were conducted to examine recall differences in learner profile groups. Chi-square analysis was used to explore the relationship between learner profile and gender.

Results

Development of the TLSI

Parallel analysis indicated nine factors to retain. This nine-factor model was specified by EFA (see Table 1 for the pattern and structure coefficients; see Table 2 for the factor correlation matrix) and confirmed by CFA (Table 3). The model showed good model fit results (YB χ^2 = 1014.708, *df* = 588, *p* < .001, CFI = .93, TLI = .92, RMSEA = .03 with a 90% confidence interval = [.03, .04], SRMR = .05). During the analysis, a total of 29 items were eliminated by reason of low factor loadings (below .30), cross-loadings in the EFA (Tabachnick & Fidell, 2001), high modification indices (implying loading on two or more subscales), or large item variances indicating a misfit in CFA. The final version of the inventory comprises 37 items in nine subscales. All subscales, with the exception of one single-item scale, contain three or more items (Costello & Osborne, 2005). Based on small changes in CFI (ΔCFI < .01), measurement invariance across gender was confirmed (Table 4; Vandenberg & Lance, 2000). The descriptive statistics of the summative scores of the subscales and reliability coefficients are presented in Table 5.

After consultation with an expert panel on self-regulated learning and text-learning strategies and detailed deliberation and examination, the following labels were ascribed to the TLSI subscales: summarizing and schematizing, highlighting, rereading, paraphrasing, linking with prior knowledge, studying titles and pictures, planful approach, monitoring, and self-evaluation (see Appendix). Highlighting, as single-item scale, was retained in the final inventory, as it represents an important distinct overt study strategy while learning from texts. Table 6 shows an overview of the relationship between the theoretical categorization of text-learning strategies and the TLSI subscales.

Table 1

Pattern and structure coefficients of EFA (sample 1)

Item	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Factor VII	Factor VIII	Factor IX
SS1	**.56 (.62)**	.17 (.29)	.12 (.21)	–.06 (.14)	–.02 (.11)	.05 (.03)	.11 (.24)	–.08 (–.12)	–.02 (–.01)
SS2	**.82 (.83)**	.01 (.13)	–.04 (.07)	.04 (.17)	–.02 (.04)	–.01 (–.06)	.03 (.18)	.03 (–.11)	–.04 (–.22)
SS3	**.87 (.88)**	.05 (.16)	–.11 (.04)	.11 (.23)	–.04 (.03)	–.03 (–.07)	–.03 (.14)	.06 (–.10)	–.05 (–.24)
SS4	**.61 (.61)**	–.08 (.06)	.13 (.16)	–.08 (.10)	.10 (.03)	.02 (.01)	–.06 (.05)	–.02 (–.11)	–.07 (–.17)
SS5	**.87 (.87)**	.04 (.16)	–.01 (.10)	–.01 (.17)	.02 (.06)	.04 (–.02)	–.04 (.12)	–.01 (–.14)	–.02 (–.20)
SS6	**.46 (.44)**	–.11 (.00)	.01 (.10)	.08 (.15)	.01 (.03)	–.10 (–.08)	.05 (.11)	–.01 (–.05)	.14 (.02)
SS7	**.85 (.83)**	.02 (.19)	.01 (.17)	–.02 (.21)	.04 (.14)	.06 (.04)	–.05 (.11)	.05 (–.06)	.02 (–.12)
HL1	.01 (.14)	.00 (.16)	.06 (.09)	.01 (.06)	.01 (.10)	–.01 (–.01)	**.80 (.80)**	.08 (.01)	–.04 (–.03)
HL2	.07 (–.07)	.00 (–.12)	.00 (–.03)	–.01 (–.03)	–.01 (–.07)	–.01 (.01)	**–.77 (–.76)**[a]	–.07 (–.09)	.03 (.03)
RR1	–.16 (–.27)	–.02 (.11)	.14 (.31)	–.07 (.10)	.07 (.18)	.06 (.18)	–.04 (–.09)	.08 (.26)	**.44 (.56)**
RR2	.01 (–.09)	.08 (.27)	.24 (.49)	–.05 (.20)	–.01 (.20)	–.03 (.13)	.01 (–.01)	.02 (.24)	**.62 (.72)**
RR3	.02 (–.10)	.11 (.30)	.14 (.45)	–.07 (.19)	.08 (.25)	–.04 (.14)	–02 (–.02)	–.02 (.22)	**.73 (.79)**
PAR1	–.04 (.08)	.10 (.24)	**.59 (.53)**	–.03 (.12)	–.05 (.12)	–.17 (–.06)	.07 (.10)	–.08 (.06)	–.01 (.17)
PAR2	–.17 (–.12)	.10 (.18)	**.30 (.36)**	.03 (.18)	–.03 (.16)	.11 (.22)	–.01 (–.03)	–.15 (–.01)	.15 (.30)
PAR3	–.06 (.03)	.17 (.32)	**.53 (.56)**	–.04 (.17)	–.01 (.21)	–.05 (.09)	.01 (.04)	–.04 (.12)	.05 (.26)
PAR4	–.03 (–.03)	–.10 (.09)	**.53 (.52)**	–.04 (.15)	–.08 (.10)	–.01 (.07)	.05 (.03)	.08 (.22)	.15 (.33)
PAR5	.03 (.03)	–.08 (.10)	**.30 (.42)**	.13 (.26)	.01 (.18)	.01 (.14)	–.02 (–.01)	.18 (.26)	.13 (.31)
PAR6	.08 (.13)	.10 (.29)	**.51 (.59)**	.03 (.25)	–.08 (.18)	.02 (.14)	–.04 (–.01)	.08 (.20)	.06 (.28)
PAR7	.07 (.11)	.01 (.17)	**.40 (.46)**	.06 (.22)	–.02 (.15)	–.05 (.07)	–.04 (–.01)	.04 (.14)	.08 (.24)
LPK1	–.02 (.06)	.04 (.20)	–.07 (.15)	–.01 (.16)	**.53 (.51)**	–.06 (.13)	.05 (.10)	.03 (.07)	.06 (.12)
LPK2	.04 (.07)	.01 (.23)	–.06 (.21)	–.09 (.17)	**.80 (.74)**	–.03 (.23)	–.04 (.03)	.01 (.06)	.03 (.11)
LPK3	.01 (.02)	–.07 (.16)	–.07 (.21)	–.02 (24)	**.80 (.76)**	.01 (.29)	.01 (.05)	–.01 (.04)	.06 (.15)
TP1	.09 (.12)	.04 (.18)	.08 (.25)	.09 (.31)	.16 (.35)	**.31 (.42)**	–.01 (.10)	–.02 (.01)	–.02 (.10)
TP2	.02 (–.03)	–.02 (.08)	–.06 (.12)	.02 (.29)	–.03 (.25)	**.78 (.76)**	.02 (.15)	.00 (.00)	.02 (.15)
TP3	–.02 (–.06)	.06 (.16)	.01 (.19)	–.04 (.27)	–.03 (.29)	**.86 (.84)**	–.01 (.14)	.04 (.05)	–.01 (.14)
PA1	.04 (–.09)	–.03 (.10)	.01 (.17)	–.04 (–.01)	.04 (.08)	–.02 (–.01)	–.06 (.19)	**.74 (.74)**	–.06 (.19)
PA2	–.06 (.08)	–.03 (–.11)	.01 (–.09)	.15 (.13)	.06 (.03)	–.03 (.04)	–.01 (–.14)	**–.70 (–.69)**[a]	–.01 (–.14)
PA3	–.05 (–.09)	–.05 (.05)	.03 (.10)	–.04 (–.01)	.05 (.08)	.03 (.03)	.14 (.08)	**.39 (.40)**	.14 (.08)
SE1	.12 (.18)	**.45 (.46)**	.09 (.18)	–.14 (–.02)	.00 (.11)	–.07 (–.04)	–.01 (.08)	–.17 (–.08)	–.01 (.08)
SE2	.01 (.11)	**.58 (.59)**	–.02 (.18)	–.01 (.09)	.09 (.23)	–.06 (.04)	–.02 (.09)	–.03 (.07)	–.02 (.09)
SE3	.02 (.09)	**.54 (.57)**	.06 (.30)	.07 (.21)	–.03 (.21)	.04 (.16)	–.10 (.24)	–.02 (.10)	–.10 (.24)
SE4	.04 (.09)	**.56 (.56)**	–.02 (.19)	–.06 (.06)	–.01 (.16)	.02 (.08)	–.06 (.19)	–.04 (.07)	–.06 (.19)
SE5	.02 (.09)	**.61 (.60)**	–.03 (.18)	–.04 (.05)	.01 (.17)	–.05 (.02)	–.01 (.14)	0.04 (.14)	–.01 (.14)
MON1	.08 (.20)	.02 (.07)	–.01 (.09)	**.36 (.38)**	–.05 (.10)	.08 (.18)	.05 (–.04)	–.09 (–.12)	.05 (–.04)
MON2	.10 (.23)	–.06 (–.01)	–.08 (.08)	**.59 (.56)**	–.03 (.14)	.05 (.22)	–.02 (–.02)	–.13 (–.18)	–.02 (–.02)
MON3	–.14 (.05)	.12 (.21)	.13 (.30)	**.52 (.53)**	.12 (.32)	–.06 (.20)	–.04 (.07)	–.03 (.01)	–.04 (.07)
MON4	–.01 (.19)	.15 (.25)	.15 (.32)	**.51 (.53)**	.08 (.28)	–.11 (.13)	–.04 (.02)	.01 (.03)	–.04 (.02)
MON5	.01 (.06)	–.30 (–.21)	–.07 (.10)	**.52 (.48)**	–.05 (.08)	.00 (.19)	.02 (.20)	–.01 (–.03)	.02 (.20)

Note. Structure coefficients are between parentheses next to pattern coefficients. Primary pattern and structure factor coefficients are in bol*df*ace. EFA = explorative factor analysis; SS = summarizing and schematizing; HL = highlighting; RR = rereading; PAR = paraphrasing; LPK = linking with prior knowledge; TP = studying titles and pictures; PA = planful approach; MON = monitoring; SE = self-evaluation.

[a]Negative pattern and structure coefficients can be ascribed to the negatively phrased item.

Table 2

Factor correlation matrix of EFA (sample 1)

	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Factor VII	Factor VIII	Factor IX
Factor I	1								
Factor II	.165	1							
Factor III	.133	.339	1						
Factor IV	.209	.167	.374	1					
Factor V	.076	.314	.367	.355	1				
Factor VI	.180	.162	.033	.046	.079	1			
Factor VII	–.048	.140	.222	.376	.376	–.028	1		
Factor VIII	–.150	.163	.223	.023	.085	.016	.015	1	
Factor IX	–.213	.185	.384	.237	.172	–.049	.179	.260	1

Note. EFA = explorative factor analysis.

Table 3

Pattern coefficients of CFA (sample 2)

Item	SS	HL	RR	PAR	LPK	TP	PA	SE	MON
SS1	.61								
SS2	.77								
SS3	.83								
SS4	.64								
SS5	.92								
SS6	.49								
SS7	.81								
HL1		1[a]							
RR1			.47						
RR2			.91						
RR3			.92						
PAR1				.52					
PAR2				.37					
PAR3				.60					
PAR4				.61					
PAR5				.51					
PAR6				.65					
PAR7				.56					
LPK1					.59				
LPK2					.75				
LPK3					.75				
TP1						.61			
TP2						.44			
TP3						.56			
PA1							.95		
PA2							.51		
PA3							.39		
SE1								.53	
SE2								.55	
SE3								.49	
SE4								.67	
SE5								.71	
MON1									.43
MON2									.58
MON3									.64
MON4									.61
MON5									.42

Note. Standardized coefficients are reported. CFA = confirmatory factor analysis; SS = summarizing and schematizing; HL = highlighting; RR = rereading; PAR = paraphrasing; LPK = linking with prior knowledge; TP = studying titles and pictures; PA = planful approach; MON = monitoring; SE = self-evaluation.
[a]The pattern coefficient of the item HL1 can be ascribed to the single-item scale. The negatively phrased item HL2 was removed from the CFA due to model conversion problems.

Table 4

Measurement invariance testing: Summary of the Goodness-of-Fit Statistics

Measurement invariance tests		Yuan–Bentler χ^2	*df*	*p*	CFI	RMSEA	ΔCFI
Configural invariance (Model 1)		1,722.867	1,176	<.001	.91	.04	
Metric invariance (Model 2)	Model 1 vs. Model 2	1,750.574	1,204	<.001	.91	.04	–.000
Scalar invariance (Model 3)	Model 2 vs. Model 3	1,792.626	1,232	<.001	.91	.04	.002
Strict invariance (Model 4)	Model 3 vs. Model 4	1,850.773	1,268	<.001	.91	.04	.004

Note. CFI = comparative fit index; RMSEA = root mean square error of approximation.

Table 5

Descriptive statistics and reliability coefficients of the different subscales

	M	SD	n_{items}	Bentler's ρ
Summarizing and schematizing	2.72	1.18	7	.89
Highlighting	4.40	1.03	1	1
Rereading	3.34	1.03	3	.82
Paraphrasing	3.10	0.85	7	.74
Linking with prior knowledge	3.39	1.10	3	.74
Studying titles and pictures	3.52	0.94	3	.65
Planful approach	3.80	1.04	3	.65
Monitoring	3.15	0.90	5	.64
Self-evaluation	4.10	0.61	5	.73

Table 6

Overview of the relation between the theoretical categorization of text-learning strategies and TLSI subscales

Classification	Subscale
Cognitive dimension	
Overt study strategies	
Text-noting strategies	Summarizing and schematizing
	Highlighting
Covert study strategies	
Reading strategies	Rereading
Mental-learning strategies	Paraphrasing
	Linking with prior knowledge
	Titles and pictures
Metacognitive dimension	
	Planful approach
	Monitoring
	Self-evaluation

Note. TLSI = Text-Learning Strategies Inventory.

Exploration of learner profiles

Hierarchical cluster analysis was conducted on the first sample to explore the presence of different cluster solutions. The first large change in agglomeration coefficients occurred when the four-cluster solution collapsed into a three-cluster solution, which was confirmed by visual inspection of the dendrogram. After examination of the subscale means in each cluster (see Table 7), four learner profiles were distinguished: integrated strategy users (ISU; n = 147; 18.8%), information organizers (IO; n = 295, 37.7%), mental learners (ML; n = 73, 9.3%), and memorizers (MEM; n = 268; 34.2%). ISU are characterized by high scores in all subscales. IO score high on text-noting strategies and report limited use of mental-learning strategies. Conversely, ML report higher mental-learning strategy use and no text-noting strategies. MEM are characterized by frequent use of one single text-learning strategy (e.g., highlighting). To validate this cluster classification, a four-cluster solution was specified in the k-means cluster analysis of the second sample and yielded similar results (34.9% ISU, 18.9% IO, 9.7% ML, and 36.5% MEM; Table 7) and curves (Figure 1). The cluster solution was additionally validated by chi-squares analyses revealing statistically significant relationships between learner profile and text markings (χ^2 = 267.07, p < .001) and scratch paper use (χ^2 = 150.99, p < .001; see Figure 2).

To explore the relationship between cluster membership and students' recall score, ANOVA was conducted. No statistically significant differences were revealed, $F(3, 534) = 2.398$, $p = .067$) between ISU ($M_{\mathrm{ISU}} = 22.56$, $SD_{\mathrm{ISU}} = 10.92$), IO ($M_{\mathrm{IO}} = 20.45$, $SD_{\mathrm{IO}} = 12.15$), MI ($M_{\mathrm{MI}} = 18.78$, $SD_{\mathrm{MI}} =$ 9.40), and MEM ($M_{\mathrm{MEM}} = 20.33$, $SD_{\mathrm{MEM}} = 10.19$), $\eta_p^2 = .013$. However, results indicate a marginal statistically significant preference for ISU, who obtained the highest recall scores. As to gender differences, a statistically significant relationship is shown between learner profile and gender ($\chi^2 = 13.18$, $p = .004$; $\varphi = .155$), revealing that more girls ($n = 103$) than boys ($n = 89$) were profiled as ISU, and more boys were identified as ML ($n_{\mathrm{boys}} = 35$, $n_{\mathrm{girls}} = 18$) and MEM ($n_{\mathrm{boys}} = 122$, $n_{\mathrm{girls}} = 79$).

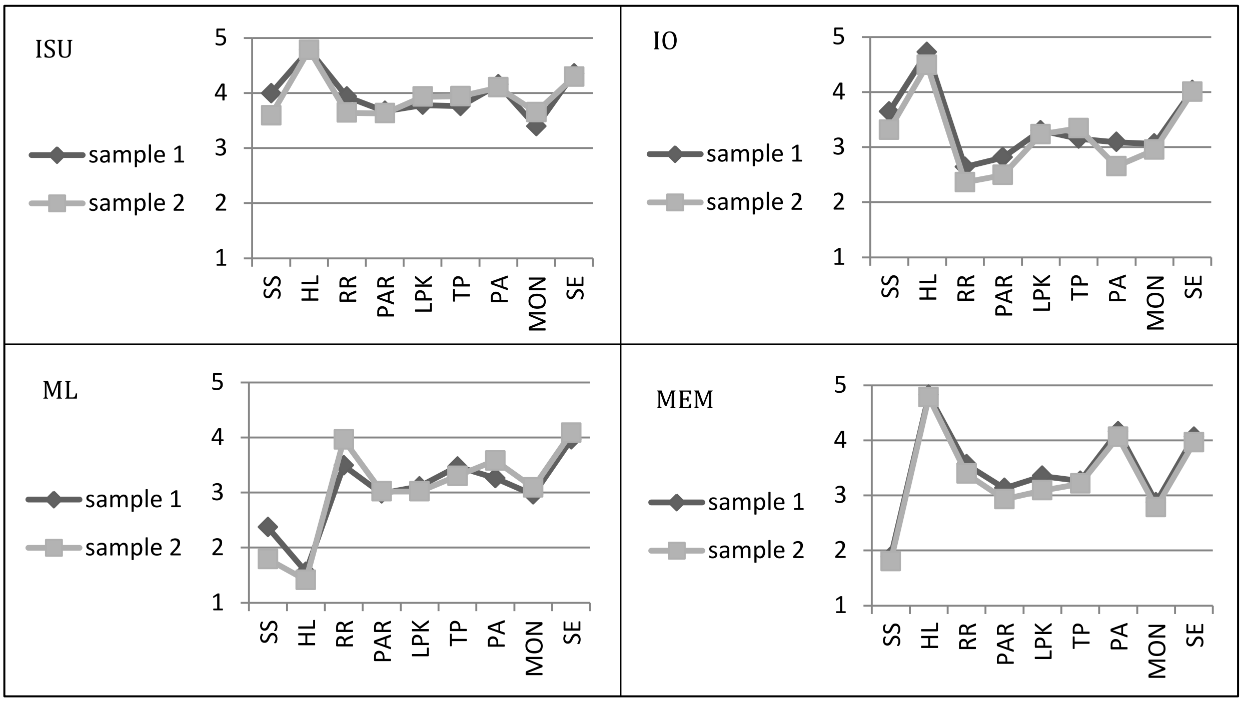

Figure 1. Mean scores of the four clusters[a] on the learning strategy subscales[b] in samples 1 and 2.

[a]ISU = integrated strategy users, IO = information organizers, ML = mental learners, MEM = memorizers. [b]SS = summarizing and schematizing, HL = highlighting, RR = rereading, PAR = paraphrasing, LPK = linking with prior knowledge, TP = studying titles and pictures, PA = planful approach, MON = monitoring, SE = self-evaluation.

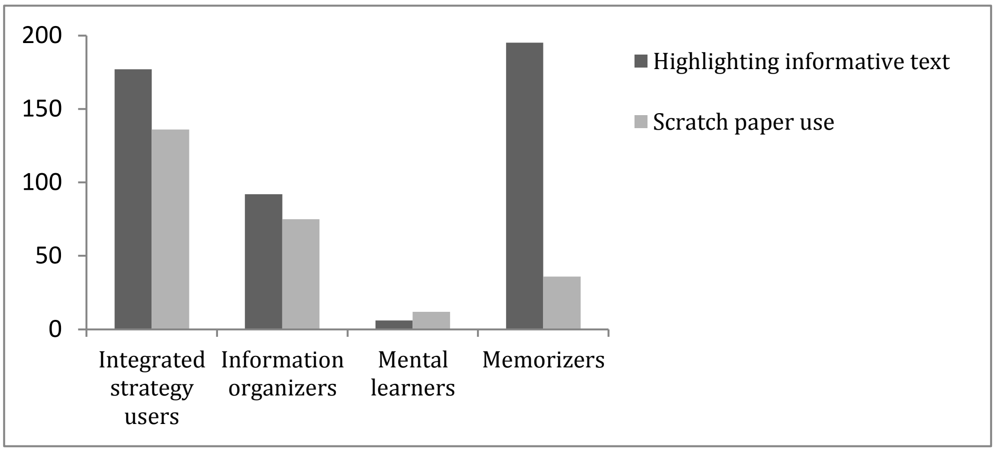

Figure 2. Occurrence of highlighting text and using scratch paper in the four clusters.

Table 7

Means and standard deviations of the classification measures per cluster

	Hierarchical clustering sample 1				K-means clustering sample 2			
	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Classification measures	Integrated strategy users (*n* = 147)	Information organizers (*n* = 295)	Mental learners (*n* = 73)	Memorizers (*n* = 268)	Integrated strategy users (*n* = 192)	Information organizers (*n* = 104)	Mental learners (*n* = 53)	Memorizers (*n* = 201)
Summarizing and schematizing	3.99 (0.51)	3.64 (0.86)	2.37 (1.20)	1.88 (0.64)	3.59 (.86)	3.31 (0.97)	1.79 (0.84)	1.80 (0.67)
Highlighting	4.78 (0.46)	4.72 (0.54)	1.56 (0.72)	4.82 (0.40)	4.80 (0.50)	4.49 (1.02)	1.42 (0.57)	4.78 (0.44)
Rereading	3.93 (0.67)	2.64 (0.91)	3.49 (1.15)	3.56 (0.97)	3.64 (0.91)	2.36 (0.78)	3.96 (0.86)	3.39 (0.94)
Paraphrasing	3.67 (0.52)	2.81 (0.73)	2.98 (0.99)	3.13 (0.81)	3.63 (0.69)	2.49 (0.62)	3.02 (0.89)	2.93 (0.79)
Link with prior knowledge	3.78 (0.85)	3.30 (1.03)	3.11 (1.17)	3.35 (1.03)	3.93 (0.85)	3.23 (1.03)	3.02 (1.23)	3.09 (1.08)
Titles and pictures	3.76 (0.81)	3.15 (1.04)	3.47 (0.93)	3.26 (1.03)	3.94 (0.80)	3.34 (0.91)	3.30 (0.89)	3.21 (0.90)
Planful approach	4.15 (0.62)	3.09 (1.12)	3.26 (1.04)	4.16 (0.78)	4.10 (0.87)	2.65 (0.99)	3.60 (0.85)	4.06 (0.87)
Monitoring	3.39 (0.75)	3.06 (0.84)	2.96 (0.80)	2.87 (0.78)	3.65 (0.70)	2.95 (0.93)	3.09 (0.99)	2.79 (0.80)
Self-evaluation	4.35 (0.46)	4.03 (0.61)	3.96 (0.76)	4.06 (0.56)	4.29 (0.52)	4.00 (0.59)	4.08 (0.69)	3.96 (0.63)

Discussion

The first research aim was to develop a task-specific self-report instrument for late elementary students, measuring spontaneously used text-learning strategies. Factor analytic results led to the TLSI, containing nine subscales. Six subscales comprising cognitive strategies were distinguished, encompassing overt (e.g., text-noting tactics) and covert (e.g., mental-learning tactics) strategies and surface- (e.g., copying information) as well as deep-level (e.g., schematizing) strategies (Kardash & Amlund, 1991; Lahtinen et al., 1997; Wade et al., 1990). Three subscales reflect metacognitive strategies (i.e., planful approach, monitoring, and self-evaluation), whereas items reflecting motivational aspects during text learning were not retained. The results provide initial evidence for using the TLSI as a valid instrument to assess and report on the use of various text-learning strategies. However, bearing in mind the possible caveats in using self-reports (e.g., memory reconstruction problems), future multi-method research is advisable. For example, self-reports can be complemented with more detailed trace data (Braten & Samuelstuen, 2007) and it can be examined how on-line measures can be used with minimal intrusion into students' learning process (Schellings, 2011).

The second research goal was to explore the presence of learner profiles based on students' self-reported strategy use. In line with previous research (Wade et al., 1990), different learner profiles could be distinguished. In particular, cluster analysis yielded four learner profiles: integrated strategy users, information organizers, mental learners, and memorizers. It is interesting that different text study approaches are already manifested in late elementary education. This means that they should be considered when providing instruction in text-learning strategies. More particularly, information organizers could be instructed in mental-learning strategies (e.g., paraphrasing) whereas mental learners could be initiated in schematizing. Memorizers could be exposed to a more diverse repertoire of TLS or grouped together with integrated strategy users, who could model for their peers the integrated use of various TLS.

However, replication and confirmation of these findings are called for in future quantitative as well as qualitative research. Furthermore, using multiple forms of assessment is advisable in assessing both prior knowledge (e.g., completion test, recognition test) and text recall (e.g., cued recall, comprehension and transfer tests). In addition, no statistically significant differences were found between students' free recall score and their learning profile. Further research could in this respect uncover the relationship between these profiles and multiple assessment measures in more depth.

To conclude, applying the TLSI in research and practice can inform elementary school teachers and researchers on students' strategy use when learning from texts. In addition, the learner profiles that have been distinguished provide a clearer view on students' strategy use and offer a starting point for the detection of ineffective or underdeveloped strategies. This allows educational researchers and teachers to develop and provide differentiated strategy instruction, attuned to students' spontaneously used text-learning strategies and aiming at instilling a set of good study skills to prepare students for "reading to learn" (Meneghetti et al., 2007). Furthermore, the suggestions for further research provide fruitful avenues for researchers investigating learning from texts in elementary education.

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Appendix

Text-Learning Strategies Inventory (TLSI)

Code	Item
What did you do while learning the text?	
Summarizing and schematizing	
SS1	I wrote a summary
SS2	I wrote down the most important information
SS3	I used scratch paper
SS4	I made a graphic organizer or a mind map
SS5	To learn the text, I used the graphic organizer or mind map on my piece of scratch paper
SS6	To learn the text, I copied it on my scratch paper
SS7	I repeated the text with my summary or graphic organizer on my scratch paper
Highlighting	
HL1	I marked the most important things
Rereading	
RR1	To learn the text, I read the text a lot of times
RR2	I repeatedly read or recalled everything until I knew it
RR3	I repeated the text until I knew it all
Paraphrasing	
PAR1	I tried to repeat the text in my own words
PAR2	In my head, I retold the information as it was written down in the text
PAR3	In my head, I retold the information from the text in my own words
PAR4	I covered up a part of the text and I tried to recall it
PAR5	I stopped once in a while to repeat
PAR6	While learning, I asked myself questions about the text and answered them to check whether I still knew what I had learned
PAR7	Afterward, I asked myself questions to check whether I still knew what I had learned
Linking with prior knowledge	
LPK1	Before learning, I thought about what I already knew about seahorses
LPK2	I related the text about seahorses to what I already knew
LPK3	I thought about what I already knew about seahorses
Studying titles and pictures	
TP1	I looked at the titles to understand the text
TP2	I looked at the pictures to understand the text
TP3	I looked at the pictures to remember the information
Planful approach	
PA1	First, I read the whole text and then I started learning
PA2	I immediately started learning, without reading the whole text first
PA3	Before highlighting, I read the paragraphs first
Monitoring	
MON1	While learning, I checked what I had already done and how much I still had to do
MON2	While learning, I asked myself: “Do I still have enough time?”
MON3	While learning, I asked myself: “Am I doing well?”
MON4	While learning, I asked myself: “Is it working well this way?”
MON5	I worried a lot about the test afterward
Self-evaluation	
SE1	I immediately knew how to start learning the text
SE2	While learning, I managed to stay attentive and concentrated
SE3	While learning, I made sure I understood everything
SE4	I managed to learn the text in a good way
SE5	I did well in learning this text

3

Using on-line and off-line measures to explore fifth and sixth graders' text-learning strategies and schematizing skills

This chapter is based on:

Merchie, E., & Van Keer, H. (2014). Using on-line and off-line measures to explore fifth and sixth graders' text-learning strategies and schematizing skills. *Learning and Individual Differences*, 32, 193-203. doi: 10.1016/j.lindif.2014.03.012

Chapter 3
Using on-line and off-line measures to explore fifth and sixth graders' text-learning strategies and schematizing skills

Abstract

This study explores the (a) text-learning strategies and (b) schematizing skills of pre-adolescents with varying achievement levels by means of the analysis of think-aloud protocols, traces, and pen movements. Twenty fifth- and sixth-grade students from two elementary schools participated. Results show the use and combination of various text-learning strategies during learning from text, mostly applied at a surface level. Notwithstanding the large variation in students' individual strategy repertoires, four main text-learning approaches could be distinguished. No achievement level differences in text-learning strategy use were found. As to students' schematizing skills, analyses illustrate the great difficulty students experience with spatially and hierarchically representing text information. Students paid limited attention in the construction process to assisting metacognitive processes. Surprisingly, low achievers spent significantly more time on those processes. This multi-method assessment of text-learning strategies in general and schematizing skills in particular provides fruitful avenues for future intervention research.

Introduction

Effective strategies for text-based learning (i.e., acquiring knowledge from text) become important prerequisites from the age of 11-13, when students spend more time on independently learning from informative texts (Bakken & Whedon, 2002; Broer, Aarnoutse, Kieviet, & Van Leeuwe, 2002). These text-learning strategies encompass activities helping students to process and acquire text information (McNamara, Ozuru, Best, & O'Reilly, 2007; Merchie, Van Keer, & Vandevelde, 2014). Schematizing is a particularly promising text-learning strategy, since the transformation of a linear text into a graphical summary helps students to represent text information in an easier to be memorized form (Broer et al., 2002; Dansereau & Simpson, 2009). The present study aims to provide insight into these text-learning strategies and schematizing skills by combining both on- and off-line measures. More particularly, think-aloud and trace methodology is combined with the rather unexplored but promising area of using pen movements to explore graphical summary (GS) construction.

Strategies for text-based learning

The transition from 'learning to read' to 'reading to learn' in late elementary education requires a shift from teaching basic reading strategies to initiating efficient autonomous strategy use supporting text-based learning (Bakken & Whedon, 2002; Pinto, Doucet, & Fernandez-Ramos, 2010). Unique text-learning strategies are therefore required helping students to process, organize, condense, and retain informative texts, which differ in many aspects from the more commonly used narrative texts (e.g., more unfamiliar vocabulary and structure, variety of text relationships) (Fang, 2008; Hall-Kenyon & Black, 2010). Building up a rich strategic repertoire is essential, as this provides a solid base on which students can rely across different curriculum subjects and learning contexts (Mok, Ma, Liu, & So, 2005).

Categorizations of text-learning strategies

Students can strategically engage in various activities during learning from texts, which can be broadly described as "any behavioral, cognitive, metacognitive or affective process or action that facilitates understanding, learning, and meaningful encoding into memory" (Weinstein, Jung & Acee, 2011, p. 137). This definition illustrates the distinction between cognitive (e.g., organization), metacognitive (e.g., monitoring), and motivational strategies (e.g., self-efficacy beliefs) (Pintrich, 2004; Weinstein, Jung, & Acee, 2011; Weinstein & Mayer, 1986). These strategies can be used overtly (i.e., text-noting tactics producing physical records) or covertly (i.e., non-observable mental-learning tactics) (Kardash & Amlund, 1991; Lahtinen, Lonka, & Lindblom-Ylänne, 1997). Furthermore, they can be applied on a surface, non-generative level (i.e., primarily aimed at basic memorization or rote learning such as rereading or literally copying texts), or on a deep, generative level, reflecting the overt transformation of text information (e.g., schematizing) (Alexander, Dinsmore, Parkinson, & Winters, 2011; Ausubel, 1968; Broekkamp & Van Hout-Wolters, 2007; Weinstein & Mayer, 1986).

Scarcity of research in elementary education

Although numerous studies, mainly executed in higher education, have already documented on the use and combination of text-learning strategies (e.g., Askell-Williams, Lawson, & Skrzypiec, 2012; Broekkamp & Van Hout-Wolters, 2007; Fox, 2009; Kardash & Amlund, 1991), few studies have specifically addressed pre-adolescents' emerging text-learning strategies. Having a thorough understanding of this age groups' strategy repertoire is crucial, however, to provide instruction attuned to their spontaneous study activities (Pressley & Harris, 2006; Slotte & Lonka, 1999). These spontaneous activities might differ according to students' general achievement, as high-achievers are found to be more effective and flexible in their strategy use, creating qualitatively better outcomes (Fox, 2009; Vauras, Kinnunen, & Kuusela, 1994).

Schematizing skills

Importance of schematizing skills

Within the wide range of text-learning strategies, the literature especially refers to stimulating deep-level generative strategies, evoking the development of a general capacity to analyze, structure, and organize knowledge, which promotes deep text processing and learning (Lahtinen et al., 1997; Nesbit & Adesope, 2006; Schnotz, 2002). Schematizing is such a deep-level generative strategy, evoking the active transformation of linear text into a graphical summary (GS). As they are spatially organized and require explicit text reorganizations, GS differ from the traditional linear summary wherein information is ordered paragraph-by-paragraph (Banikowski, 1999; Crawford & Carnine, 2000; Newell, 2006). By illuminating the text's gist and clarifying text relationships, a GS helps students to process and structure large amounts of texts and serves as a synoptic learning tool (Dansereau & Simpson, 2009; Pinto et al., 2010; Vekiri, 2002). This line of reasoning is endorsed by the Dual Coding Theory (Paivio, 1991) and the Cognitive Load Theory (Sweller & Chandler, 1994; Sweller, van Merriënboer, & Paas, 1998), pointing to advantages in text recall and the decrease of cognitive load due to the simplification of the complex text relationships.

A product- and process-oriented perspective

Schematizing skills can be viewed from a product-oriented as well as from a process-oriented perspective (Alamargot, Chesnet, Dansac, & Ros, 2006; Alamargot, Plane, Lambert, & Chesnet, 2010; Berninger, Fuller, & Whitaker, 1996). From a product-oriented perspective, these skills encompass the ability to create a well-organized hierarchically structured product by meaningfully selecting and arranging key words. From a process-oriented perspective, schematizing includes three sequential phases (Alamargot et al., 2006; Alamargot et al., 2010; Berninger et al., 1996). In the planning or pre-writing phase, students prepare the content of their GS by reading, interpreting, or structuring text. In the construction or writing phase, students develop their GS by analyzing, synthesizing, and transposing the text into a hierarchically structured spatial arrangement. In the revising or post-writing phase, the GS is evaluated and revised when necessary. During these sequential phases, various processes are elicited (Hilbert & Renkl, 2008). Few studies have specifically addressed pre-adolescents' schematizing skills, especially from a process-oriented perspective. Although previous research has already focused on the quality of elementary students' GS products (e.g., Broer et al., 2002; Merchie & Van Keer, 2013), little empirical evidence exists on the dynamic schematizing process itself. Capturing this process is additionally challenging, as to date no studies have explored this in pre-adolescence by means of on-line measurements (i.e., during task execution).

Research questions

The following research questions were investigated:

1. The first research question (RQ1) concerns pre-adolescents' text-learning strategies.
   a. To which extent do fifth and sixth graders use text-learning strategies spontaneously?
   b. Are text-learning strategies strategically and consistently combined into a strategy repertoire? Can students be grouped on this basis?
   c. Do achievement-level differences exist in students' text-learning strategies?
2. The second research question (RQ2) concerns depicting students' schematizing skills from a product- and process-oriented perspective.
   a. To which extent are students skilled in creating a graphical summary?
   b. Can the dynamic schematizing process be explored by means of pen movements?
   c. Do achievement-level differences in students' schematizing skills exist?

Method

Participants

This study was carried out in 4 classes from two different schools. Twenty students participated, ten fifth and ten sixth graders with an overall mean age of 11.84 (SD=0.62). There were 7 boys (35%) and 13 girls (65%). The majority of the students (95%) were native speakers of Dutch, the instructional language in Flanders (Belgium). One student had a different home language (French). In order to compare students with different achievement levels, classroom teachers were asked to select students with a varying achievement level (Vauras et al., 1994). In this respect, 6 high achievers, 8 average achievers, and 6 low achievers participated in this study. The achievement-level distinction was corroborated with a researcher-designed text study test, with scores ranging from 12 to 58, showing significant differences between the scores of high-achievers (M=39.67, SD=16.37), average-achievers (M=32, SD=8.75) and low-achievers (M=19.33, SD=7.87) (F(2,19)=4.493, p=.02). Informed consent was obtained for all participating students.

Instruments and procedure

Analysis of think-aloud protocols, traces, and pencasts

First, with regard to the process-oriented perspective of this study, a *think-aloud methodology* was used to gain insight into the ongoing processes during text learning and schematizing. The validity of this on-line data-gathering method has been shown repeatedly in text learning research (Fox, 2009; Greene, Robertson, & Croker Costa, 2011; Schellings, Aarnoutse, & van Leeuwe, 2006; Scott, 2008; van Someren, Barnard, & Sandberg, 1994; Young, 2005). More particularly, students were instructed to verbalize their thought processes and the used strategies concurrent to task execution (Scott, 2008; Veenman, 2011). Prior to the task administration, participants received a 20-minute individual practice (van Someren et al., 1994). Hereafter, they were instructed to complete a learning and schematizing task. They were reminded to think aloud when necessary, although as little as possible. Students' verbal reports and non-verbal behavior (i.e., structuring texts, making annotations) from the audio- and videotaped recordings were transcribed, resulting in think-aloud protocols (TAP). Second, also *trace methodology* (i.e., scoring marks and notes in the informative texts, scratch papers, and GS) was applied (Braten & Samuelstuen, 2007; Winne, 2010). Third, an *analysis of pen movements* complemented think-aloud data and traces in the schematizing task. This method, already applied in the field of writing research (Alamargot et al., 2006; Alamargot et al., 2010) is, to our knowledge, new in schematizing research. Students' pen movements were captured by means of a digital Livescribe® writing pen with a built-in microphone. Students schematized on special micro-doted paper, which simultaneously registers pen movements and verbalizations. This results in playable movies of the schematizing process ('pencasts'). Figure 1 illustrates the assignment situation of the schematizing task.

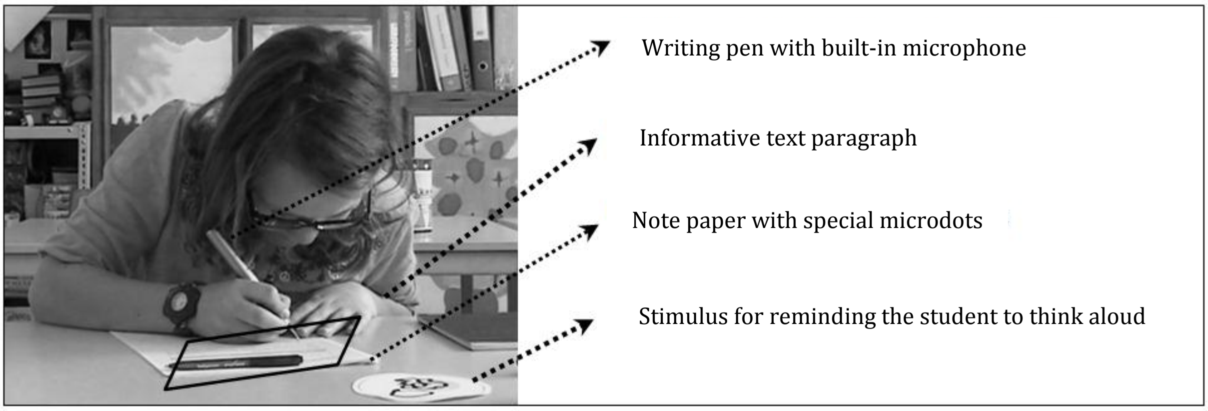

Figure 1. Assignment situation of the schematizing task.

Learning and schematizing task

Students were individually tested in a separate classroom, where they completed a learning task and a schematizing task. During the learning task, students were instructed to study a 300-word informative text in the same way as they would do to prepare for a test (Fox, 2009). The informative text entitled 'the wonderful world of seahorses' consisted of three central subtopics accompanied with a picture: general information, body parts, and living environment. Text readability and level of difficulty were evaluated in advance by presenting the text to a panel (comprising a text learning expert, an elementary school teacher, and a student) and implementing it into a pilot-test in one fifth- (n=17) and one sixth-grade class (n=18). Students' text interest was assessed by asking them to indicate their interest in the topic on a 5-point Likert scale. The text covered an interesting topic (*M*=4.15, *SD*=.81). Students were allowed, but not obligated to use a scratch paper (Slotte et al., 2001). After completing the learning task, a schematizing task was administered. Students who did not exactly knew what a GS was (45%) received a short description: “a graphical summary is an overview of the ideas in the text paragraph, linked together in a certain way”. No further construction guidelines were given (Hilbert & Renkl, 2008). Students were instructed to continue thinking aloud during schematizing a 75-word text paragraph from the previously studied informative text with the digital writing pen. Revisions could be made by crossing-out and rewriting to study the rate of spontaneous revising (Alamargot et al., 2010).

Coding instruments

Three different instruments (i.e., a coding instrument for analysis of the TAP and two rubrics for trace analysis) were constructed. A thorough literature review preceded the development of the TAP-coding instrument, inventorying various text-learning strategies. In this respect coding categories were derived from a large pool of previously published studies on self-regulated learning and learning from texts reporting on various sorts of strategy measurements, including task-specific learning strategy questionnaires (e.g., Biggs, 1987; Braten & Samuelstuen, 2007; Entwistle & McCune, 2004; Merchie et al., 2014; Pintrich, Smith, Garcia, & McKeachie, 1991; Schmeck, Geisler-Brenstein, & Cercy, 1991; Vandevelde, Van Keer, & Rosseel, 2013; Weinstein & Palmer, 2002), and think aloud protocols (e.g., Braten & Stromso, 2003; Broekkamp & Van Hout-Wolters, 2007; Cromley & Azevedo, 2006; Linderholm & van den Broeck, 2002; Meijer, Veenman, & van Hout-Wolters, 2006; Tuckman & Monetti, 2010; Wade, Trathen, & Schraw, 1990). In the developed coding instrument, codes are classified into 12 main categories (i.e., text structuring, scratch paper noting, studying pictures, elaboration, scratch paper learning, rereading or retelling text, paraphrasing, memorizing pictures, text orientation, monitoring, self-evaluation, and motivational statements), each subdivided into different subcategories (Appendix). These coding categories correspond to the learning strategy description discussed in the theoretical framework, reflecting overt (e.g., text noting activities), and covert (e.g., mentally rehearsing), cognitive (e.g., elaboration strategies), metacognitive (e.g., monitoring), and motivational (e.g., self-efficacy beliefs) text-learning strategies. Think aloud-transcripts were segmented by one researcher into different code meaning or analysis units wherein a phrase, or group of sentences are identified as a single thought process or approach representing a single text-learning strategy (Chi, 1997; Scott, 2008; van Someren et al., 1994). 31% of the protocols were double-scored by two independent trained coders, resulting in a high interrater reliability (Krippendorff’s α = .91) (Hayes & Krippendorff, 2007).

Further, two scoring rubrics were composed for trace analysis in the learning and schematizing task to study the occurrence and quality of specific text or scratch paper notes (e.g., Braten & Samuelstuen, 2007; Meier, Rich, & Cady, 2006; Nitko & Brookhart, 2007). The learning task-rubric contains two broad categories: ‘informative text’ (e.g., title and paragraph markings, inclusion of structural cues) and ‘scratch paper’ (e.g., structure of written information). The schematizing task-rubric was inspired by previously developed GS-scoring rubrics (e.g, Hilbert & Renkl, 2008; Lee & Nelson, 2005; Merchie & Van Keer, 2013; Taricani & Clariana, 2006). Different components of a good graphical summary were identified (e.g., hierarchical structure, integration of information) and verified.

Finally, the coding system of Hilbert and Renkl (2008) was used as a guideline for the analysis of the on-line think-aloud transcripts during schematizing. This system comprises ten distinct coding categories (e.g., elaboration of concepts, relevance, relationships, planning and controlling, activity reports) (Hilbert & Renkl, 2008).

Coding procedure

Off-line and on-line analysis were executed with the different coding instruments (Table 1). As to the on-line analysis of the learning task, 320 minutes thinking aloud and 1080 meaningful units were coded quantitatively according the developed TAP-coding instrument. The most meager protocol counted 10 coded activities, whereas 192 activities were found in the richest protocol. Mean number of activities per protocol was 45 (SD = 42.16). First time text reading was not included into the analysis. However, as an indication of text orientation, it was examined how much students chose to read the complete text before executing different text-learning strategies. Mean study time was 16 minutes (SD = 8.06), with a minimum of 7 and a maximum of 43 minutes. An off-line trace analysis complemented the on-line analysis of the learning task. By means of the learning task-rubric, different elements in the informative texts and scratch papers were scored. Similarly to the learning task, off- and on-line analyses were conducted for the schematizing task. For the on-line analysis, temporal characteristics of the writing period duration (i.e., pre-writing, construction, and post-writing) (Alamargot et al., 2010) and gradual construction (e.g., following the text sequence) were assessed. Also the number of revisions was explored. As to the off-line analysis, final assignments products were scored with the schematizing task-rubric.

Table 1
Overview of the coding instruments for on-line and off-line analysis

	On-line analysis: Think aloud protocols and pen movements	Off-line analysis: Traces
Learning task	TAP-coding instrument (Appendix)	Learning task rubric (Table 3)
Schematizing task	TAP-coding instrument (Hilbert & Renkl, 2008) Pen movement analysis: Temporal characteristics of pen movements Revisions made	Schematizing task rubric (Table 5)

Data analysis

To answer the first research goal concerning text-learning strategies, the actual occurrence of the different text-learning strategies was calculated per participant. Descriptive analyses were conducted to verify the frequency to which students applied and combined specific text-learning strategies. In addition, the scores on the rubrics were analyzed descriptively. Parallel, descriptive analyses of both the schematizing process and the GS-product were performed to answer the second research question. Kruskal-Wallis one-way analysis of variance (Kruskal & Wallis, 1952) and chi-square analyses were used to test achievement-level differences in text-learning strategies and schematizing skills. Fisher's exact test was used in the chi-square analysis as the expected frequencies in each cell was less than 5 (Fisher, 1922).

Results

Research question 1. Text-learning strategies.

Pre-adolescents' text-learning strategies (RQ1a)

Table 2 presents the frequencies and percentages of students' text-learning strategies combined with the numbers of protocols showing these activities and the maximum number within one protocol.

Overt cognitive text-learning strategy use. Regarding text-learning strategies leaving physical records, 13.8% units were coded as text structuring, 18% as scratch paper-noting. Within the twelve protocols showing these activities, half of the students simultaneously read and highlighted text. When linking these coded overt activities to the off-line trace methodology results (Table 3), it appears that only a third of the students marked (sub)titles and selected key words and sentences in the paragraphs. Hardly any student added additional structural cues or used different color codes to indicate hierarchical structure. Only 1 of the 11 students using a scratch paper ordered the information graphically.

Covert cognitive text-learning strategy use. As to the covert cognitive text-learning strategies, most coded units fall within the subcategories 'rereading or retelling the text' (24.2%). Three quarters of the students engaged in rereading the text for memorizing, but far less protocols showed the engagement in scratch paper learning activities (17%). The majority of the students adverted to the pictures in the text, however, very few students explicitly linked the pictures to the text. Less of half of the participants engaged in elaboration strategies (e.g., relating prior knowledge to the text), reflected in only 4.4% coded units. Less units reflected 'paraphrasing' (3%) and 'memorizing pictures' (1.1%).

Covert metacognitive text-learning strategy use. Few students engaged in text scanning or overviewing the text before reading (1.7% coded units). Slightly more but still few units (3.5%) reflect monitoring strategies. More units were coded as self-evaluation during text learning (9.7%), largely due to the fact that almost half of the students made efforts to verify text retention. However, only few students insert rehearsal moments or engage in self-questioning to verify retention.

Motivational text-learning strategy use. Remarkably, no units were coded as motivational strategies during text learning.

Students' individual strategy repertoire and strategy repertoire group (RQ1b)

In a next step, the combination of strategies, the individual frequency of occurrence, and the variation between students' strategy repertoires was examined. Figure 2 shows students' individual strategy-repertoire, based on the frequency of the coded units in their TAP. Despite the large variation between students, four general text-studying approaches can be observed. First, almost half of the participants either possess a very small strategy-repertoire (e.g., student 19) or spend very little time on the various executed strategies (e.g., student 14). Second, other students (e.g., 11 and 12) only frequently use one single text-learning strategy (e.g., rereading). A third group addresses a richer strategy repertoire to a higher extent although less strategically combined (i.e., structuring or summarizing text, but not appealing to this for text learning). Finally, a fourth group addresses a rich strategy-repertoire in a varied and strategic way. Student 1 to 4 strategically combine in this respect 'text structuring' and 'scratch paper noting' with text and scratch paper learning (cfr., horizontal connections in Figure 2). These four strategy repertoire groups were verified and confirmed with an explorative hierarchical cluster analysis in SPSS, using Ward's method with the squared Euclidean distance similarity measure (Hair, Anderson, Tathm, & Black, 1998; Henry, Tolan, & Gorman-Smith, 2005). Frequencies on the main text-learning strategy categories were used as cluster variables. The four repertoire groups could be confirmed after visual inspection of the dendrogram and fixing the analysis on a 4-cluster solution to verify cluster membership.

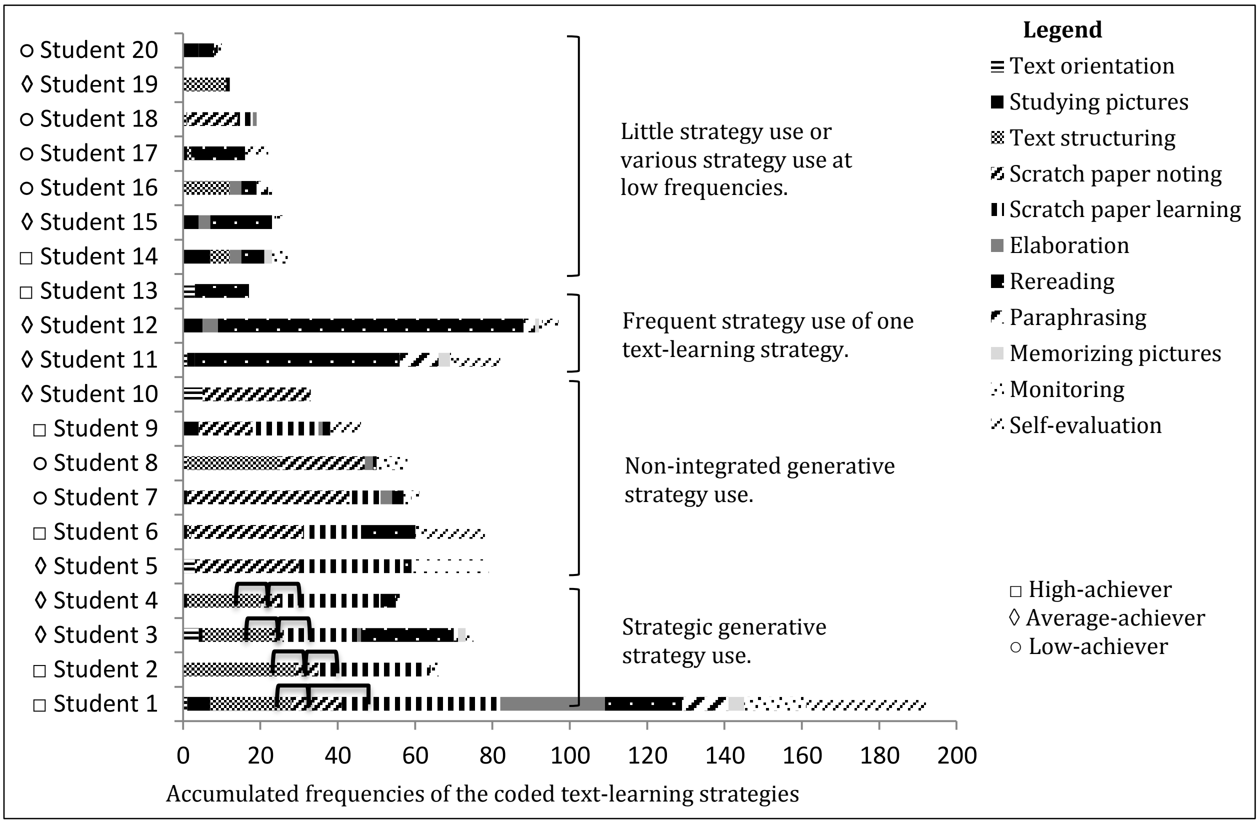

Figure 2. Overview of students' individual strategy repertoire.

Table 2

Text-learning strategies: Descriptive information of the 1080 coded think-aloud units

	Frequencies	Percentage (%)	Number of protocols showing	Maximum number within 1 protocol
Text-structuring	**149**	**13.8**	**12**	**29**
Simultaneously reading and highlighting	99	9.2	7	24
Indicating relevant information for highlighting	17	1.6	7	7
Marking text sentences	9	.8	2	7
Marking key words or key sentences	11	1	2	8
Marking titles and subtitles	9	.8	5	3
Marking figures	3	.3	3	1
Using different colours	1	.1	1	1
Scratch paper noting	**195**	**18.1**	**11**	**42**
Instant linear summary	7	.6	2	6
Rereading for schematizing	51	4.7	8	13
Linear summary – key words	52	4.8	7	13
Linear summary – key sentences	57	5.3	8	31
Linear summary – paraphrasing text	5	.5	3	2
Linear summary – structuring scratch paper	13	1.2	6	3
Graphical summary	10	.9	2	7
Studying pictures	**37**	**3.4**	**12**	**7**
Explicitly studying pictures	27	2.5	12	4
Relating pictures to text information	10	.9	3	5
Elaboration	**48**	**4.4**	**10**	**27**
Activating prior knowledge	1	.1	1	1
Relating prior knowledge to the text	19	1.8	7	8
Imagining text information	28	2.6	7	18
Scratch paper learning	**185**	**17.1**	**9**	**41**
Retelling scratch paper by heart	7	.6	3	4
Rereading scratch paper	47	4.4	3	27
Covering up scratch paper	13	1.2	3	8
Copying text information	118	10.9	4	40
Rereading or retelling the text	**261**	**24.2**	**17**	**79**
Rereading for memorizing	88	8.1	15	19
Rereading with emphasis on certain keywords	20	1.9	5	7
Literally retelling	104	9.6	11	41
Scanning or retelling highlighted information	6	.6	5	2
Covering text information and trying to retell literally	43	4	3	22
Paraphrasing	**32**	**3**	**8**	**12**
Memorizing pictures	**12**	**1.1**	**5**	**4**
Text orientation	**18**	**1.7**	**7**	**5**
Scanning the text before reading	3	.3	3	1
Reading the whole text before learning	15	1.4	4	5
Monitoring	**38**	**3.5**	**10**	**16**
Checking progress	1	.1	1	1
Rereading difficult words	4	.4	2	2
Stating incomprehension	16	1.5	7	6
Stating comprehension	13	1.2	3	8
Difficulty with text content	4	.4	3	2
Self-evaluation	**105**	**9.7**	**11**	**31**
Verifying in the text	63	5.8	9	19
Structuring scratch paper to verify what is learnt	10	.9	2	6
Inserting intermission to rehearsal	4	.4	3	2
Self-questioning	10	.9	4	5
Rehearsal by heart	10	.9	3	7
Noticing memory failure	8	.7	3	5
Motivational statements during text learning	**0**	**0**	**0**	**0**

Table 3

Off-line analysis of the marks and notes in the informative text and scratch paper

	Frequencies	Percentage (%)
Informative text		
Highlighting titles		
No highlighting	14	70
Marked only title	0	0
Marked title and most subtitles	3	15
Marked titles and subtitles	3	15
Highlighting paragraph information		
No highlighting	12	60
Sentences, large text units	1	5
Sentences and key words	2	1
Key sentences and key words	5	25
Key words representing gist of the text	0	0
Including structural cues		
Adding structural cues in the text (e.g., arrows, numbers)	0	0
Use of different highlighting colors	1	5
Noting key words in the text margin	0	0
Scratch paper		
No scratch paper noting	9	45
Linear summary with sentences or paraphrases	4	20
Linear unstructured summary with key words	2	10
Linear structured summary with key words	4	20
Structured graphical summary	1	5

General achievement level differences (RQ1c)

Table 4 provides descriptive information on the occurrence of the different text-learning strategies according to students' achievement level. No significant differences in strategy use were found according to students' achievement level for text-structuring (χ^2= .321, *df*= 2, *p*= .859), scratch paper noting (χ^2= .572, *df*= 2, *p*= .764), studying pictures (χ^2= 1.433, *df*= 2, *p*= .505), elaboration (χ^2= .626, *df*= 2, *p*= .752), scratch paper learning (χ^2= 2.806, *df*= 2, *p*= .259), rereading or retelling text (χ^2= . 1.562, *df*= 2, *p*= .474), paraphrasing (χ^2= .450, *df*= 2, *p*= .822), memorizing pictures (χ^2= 2.647, *df*= 2, *p*= .367), text orientation (χ^2= 2.342, *df*= 2, *p*= .298), monitoring (χ^2= 3.278, *df*= 2, *p*= .201), and self-evaluation (χ^2= 1.000, *df*= 2, *p*= .626). Chi-square analyses furthermore revealed no significant association between general achievement level and strategy-repertoire group (*p*=.518).

Research question 2. Students' schematizing skills.

Graphical summary - Product (RQ2a)

First an off-line analysis was executed to assess the quality of students' GS (Table 5). One fourth of the students did not succeed in spatially linking the text information, as they copied the text sentences linearly. For the 15 students who did schematize, 8 students used a tree diagram, 2 students drew a sequence diagram, and 2 students combined a sequence and tree diagram. Three students drew a web organizer. Although most of the students represented well-chosen key words into an integrated entity, hardly any distinction was made between main and subordinate ideas. Only one student worked out a GS in a well-organized, hierarchically structured way.

Table 4

Descriptive information on the frequencies of observed text-learning strategies according to students' achievement level

	High-achievers		Average-achievers		Low-achievers	
	M	*SD*	*M*	*SD*	*M*	*SD*
Text structuring	9.33	12.53	6.87	8.25	6.33	9.81
Scratch paper noting	10.33	10.97	7	10.86	12.83	16.9
Studying pictures	3	3.09	1.63	1.92	1	1.55
Elaboration	5.17	10.75	1	1.6	1.5	1.38
Scratch paper learning	16.83	15.99	9	12.64	2	3.35
Rereading or retelling	9.33	7.87	22.38	29.02	4.33	5.01
Paraphrasing	2.17	4.83	1.88	3.44	0.67	1.21
Memorizing pictures	1	1.67	0.75	1.16	0	0
Text orientation	0.67	1.21	1.63	2.07	0.17	0.41
Monitoring	4	6.07	0.38	0.52	1.833	3.13
Self-evaluation	9.17	12.46	5.13	7.2	1.5	2.35

Table 5

Off-line analysis of the graphical summary products

	Frequencies	Percentage (%)
General Structure		
No graphical structure	5	25
Tree diagram	8	40
Tree + sequence diagram	2	10
Sequence diagram	2	10
Web graphic organizer (mind map)	3	15
Integration		
Linear key sentences or words (no	7	35
integration)	2	10
Several separate units	10	50
Integrated but disorderly GO	1	5
Well-organized GO		
Starting point		
No clear starting point	8	40
Irrelevant or to broad	7	35
Relevant and well-chosen	5	25
Key word choice		
Copying text sentences	2	10
Copying key sentences	8	40
Generally well-chosen key words	5	25
Relevant and well-chosen key words	5	25
Hierarchical structure		
No distinction main and sub ideas	11	55
Incorrect order main and sub ideas	5	25
Generally correct order main and sub ideas	3	15
Good distinction main and sub ideas	1	5

Graphical summary – Process (RQ2b)

Findings from the off-line analysis were complemented with the on-line analysis of students' think-aloud transcripts. Students however did experience great difficulty with thinking aloud during schematizing. In this respect, all students' statements could be classified into the categories of 'reading aloud', 'activity reports' (i.e., describing what they are doing without referring to the content such as 'I am copying this word into my graphical summary') or 'non-content problems' (i.e., problems with GS construction such as 'I don't know how to do this') (Hilbert & Renkl, 2008). Therefore, these verbal transcripts were not viable for a more in-depth data-analysis of possible interplaying (meta)cognitive processes.

The analyses of pen movements on the other hand, did allow us to shed a light on the dynamic schematizing process. Figure 3 provides an example of some gradually composed graphical summaries. The overall schematizing process took on average 273 seconds (SD = 71 seconds). Mean time of the pre-writing phase was 21 seconds (SD = 16 seconds), nearly always spent on reading the text paragraph which could be verified by inspecting the think aloud transcripts. Five students immediately started schematizing. The GS construction phase took on average 244 seconds (SD = 66 seconds). Almost all students followed the linear text sequence. One student (Figure 3, student 19), however, seems to have inspected the text structure previously as he splits up the starting point at the beginning into two different sections to elaborate on them subsequently. The post-writing phase lasted on average 8 seconds (SD = 11 seconds). Seven students indicated to have finished the task immediately after GS construction. Three students made post-writing revisions by adding information to the GS after rereading the text.

Achievement level differences in schematizing skills (RQ2c)

No differences were found on the different sub-rubrics (general structure, p=.950; integration, p=.426; starting point, p=.770; key word choice, p=.840; hierarchical structure, p=.861). Descriptive information on the schematizing task sub-rubrics' scores according to students' achievement level can be found in Table 6.

As to the construction process, no significant differences were found for the pre-writing (χ^2= .978, df= 2, p= .635) and construction phase (χ^2= .316, df= 2, p= .868). However, low-achieving students spent significantly more time on the post-writing phase (χ^2= 6.629, df= 2, p= .029) than high- and average-achievers. Figure 4 illustrates the duration of the different schematizing phases according to students' achievement level.

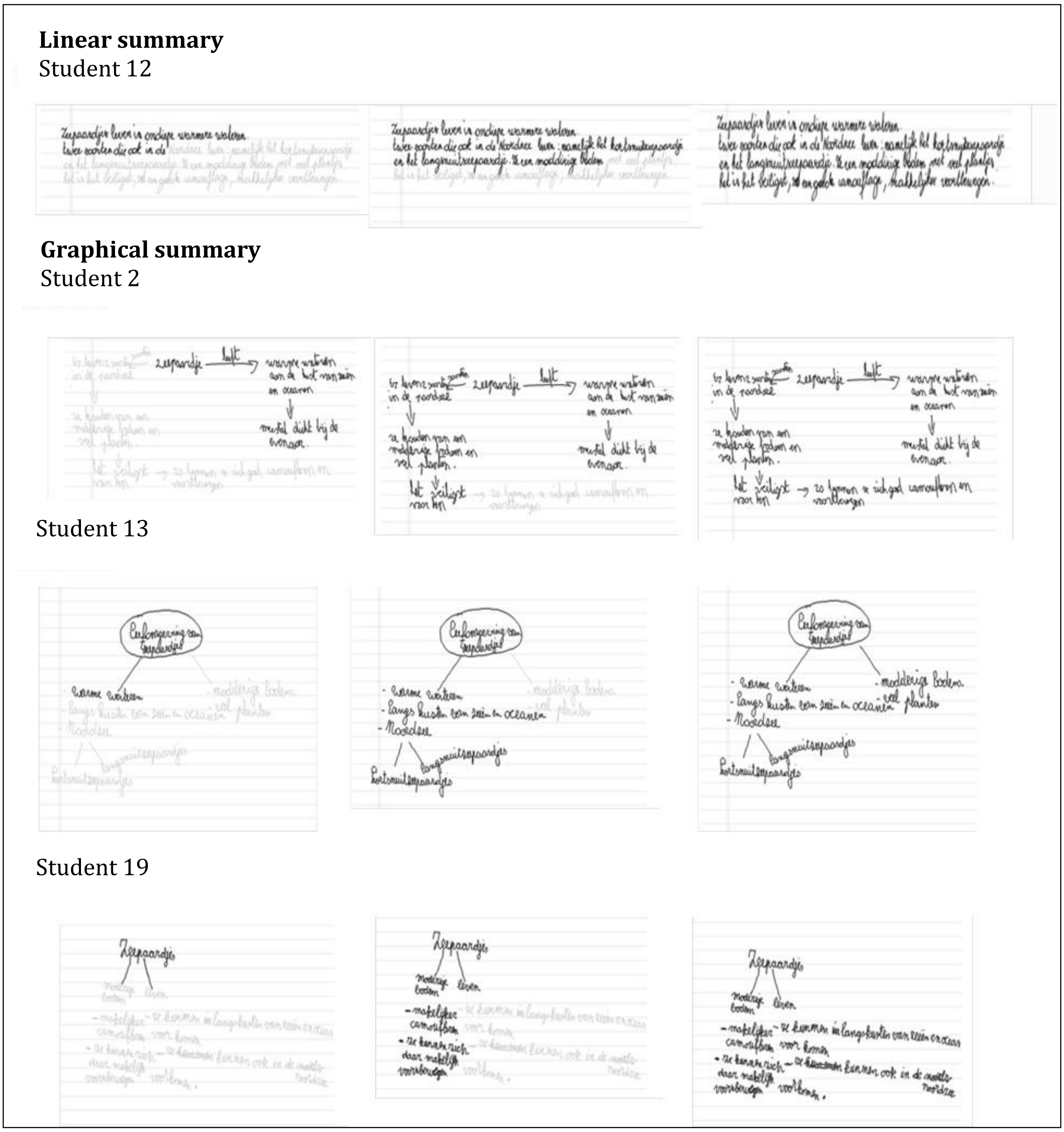

Figure 3. Overview of the dynamic GS construction process.

Note. During the pencast play, the light grey text information turns black according to how the summary was gradually constructed by the student.

Table 6
Descriptive information on the schematizing task sub-rubrics' scores according to students' achievement level

	High-achievers		*Average-achievers*		*Low-achievers*	
	M	*SD*	*M*	*SD*	*M*	*SD*
General Structure	1.33	1.03	1.63	1.60	1.50	1.64
Integration	2.00	1.10	2.63	1.06	2.00	0.89
Starting point	1.83	1.17	2.25	1.16	2.17	1.47
Key word choice	2.50	0.84	2.75	1.04	2.67	1.21
Hierarchical structure	1.67	1.21	1.88	1.13	1.17	0.75

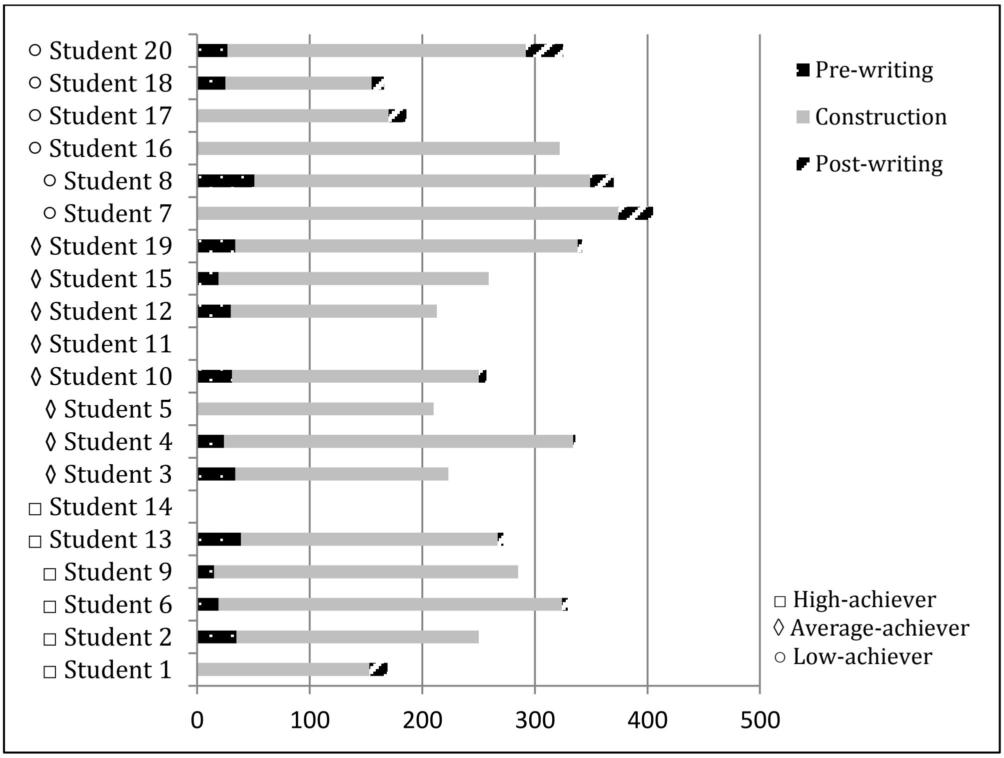

Figure 4. Duration (in seconds) of the schematizing phases according to general achievement level.
Note. Two pencasts were excluded from the analysis as they demonstrated technical problems.

Discussion

Discussions on the current study

Text-learning strategies. Strategic, deep-level generative strategy use supporting text-based learning becomes indispensable from late elementary education on. The first goal of this study was to provide insight into pre-adolescents' emerging text-learning strategies, as they provide a base for strategy initiation and stimulation. By combining on-line and off-line measures (i.e., think-aloud protocols and traces), the occurrence and quality of various overt and covert cognitive and metacognitive text-learning strategies could be revealed. With regard to overt cognitive text-learning strategies, half of the students engaged in some sort of active text manipulation. However this was applied rather ineffectively and superficially by simultaneously reading and highlighting, marking complete text passages and linearly copying text information (Broekkamp & Van Hout-Wolters, 2007; Meneghetti, De Beni, & Cornoldi, 2007). Students engaged to a lesser extent in covert cognitive (e.g., elaboration) and metacognitive (e.g., monitoring) text-learning strategies. Here, mainly surface-level strategies (i.e., aiming at rote learning such as rereading) were used as well. As to the metacognitive strategies, most students skipped text orientation (e.g., scanning the text), even though this is a first important step in text learning (Meijer et al., 2006). Studying students' individual strategy repertoires revealed four main approaches to informative text learning. A first group either used little strategies or combined various strategies at a low frequency. A second group frequently used one single text-learning strategy. A third group addressed a richer strategy repertoire although less consequently. For example, students who did condense the text on their scratch paper not always applied this summary as a synoptic tool for learning. A fourth group engaged more deliberately and strategically in various text-learning strategies. These findings complement and extent previous work studying the combination of (text-)learning strategies in older age groups (e.g., Rheinberg, Vollmeyer, & Rollett, 2002; Wade et al., 1990). Finally, students' general achievement level seemed not to be related to either text-learning strategy use or belonging to a specific strategy-repertoire group. In conclusion, these results show that deep-level generative strategy use and the deliberative and strategic combination of various text-learning strategies in this age group is still in its infancy, and this applies to all achievement levels.

Schematizing skills. An important precondition to effectively apply deep-level generative strategies in text learning is being able to perform these particular strategies (Broekkamp & Van Hout-Wolters, 2007). Therefore, the second research goal was to specifically focus on pre-adolescents' schematizing skills. Off-line analyses of the graphical summary product revealed the great difficulty students experienced with hierarchically and spatially representing text information. On-line analyses of the schematizing process show that only few students explicitly engaged in the metacognitive activities of planning or revising their GS. The limited time spent on orientating activities during pre-writing however might be attributable to the fact that students schematized a previously studied text content. As to the achievement-level differences, it was surprising that low-achievers devoted more time on the post-writing phase than high- and average-achievers. Possibly, their task uncertainty triggered them to overview their GS longer. These findings clearly indicate that the participants' schematizing skills are still for a large part undeveloped. This might furthermore explain why almost no student has created a GS during text studying and most students fall back on surface-level, reproductive strategies.

Limitations and implications for future research

The results of this study must be complemented with six concrete concerns, to be considered as entries for future research. First, although thinking-aloud allowed to gain insight into the more covert text-learning strategies, some think-aloud protocols might have been incomplete as thinking aloud might have been too intrusive for poorer readers or some processes may not be elicited (Scott, 2008). Second, motivational strategies (e.g., self-efficacy) were not elicited in this study. This might be due to the unconscious presence of motivation without active regulative control (Wolters, Benzon, & Arroyo-Giner, 2011) as all students conscientiously executed both tasks. Third, the sample size of this study was rather small, attributable to the time and labor insensitivity of the data gathering and analysis method. Although this allowed to document more detailed on students' individual differences in text-learning strategy use and this is in line with previously conducted think aloud-studies (e.g., Braten & Stromso, 2003; Coté, Goldman, & Saul, 1998; Schellings & Broekkamp, 2011), future larger scale research is advised to complement the research findings. In this respect, traces reflecting overt processes, could be complemented with task-specific self-report measures. These self-reports might provide more insight into the more covert cognitive, metacognitive, and motivational text-learning strategies (Braten & Samuelstuen, 2007; Schellings & Van Hout-Wolters, 2011). Further, studies with lager sample sizes could comprise more homogeneous achievement level groups and will result in more power for the analyses. Fourth, it is also possible that students might have had different test expectations, which could have influenced their used text-learning strategies (Schellings & Broekkamp, 2011). Further research could uncover students' strategy adaption more in detail and compare the uncovered strategy use in this study with strategy use addressing diverse task demands. Fifth, the learning task in this study was immediately followed by a schematizing task, involving the same text content. This might not only have influenced the time spent on orientating activities during pre-writing but also other aspects of the GS construction process or final products. A follow-up study using different texts in both tasks could examine whether and how this specific research design might have possibly affected the results. A final concern relates to the great difficulty students experienced with verbalizing their thought processes during schematizing. This might be explained by the additional cognitive demands related either to the task difficulty of the schematizing task or to the still underdeveloped verbalization skills to describe those specific cognitive operations (Braten & Samuelstuen, 2004; Scott, 2008; van Someren et al., 1994; Veenman, 2011). Therefore, future research with older participants is encouraged (Cromley & Azevedo, 2006), as well as studies involving methods that stimulate students to explain their schematizing activities in general and non-content problems in particular (e.g., self-explanation, videotaped sessions with retrospective reports) (Schellings & Broekkamp, 2011).

Contributions and pedagogical implications

The present study was carried out into students' natural school environment using off- and on-line data gathered with three different methodologies (i.e., think-aloud protocols, trace methodology, and pen movements). By combining both process- and product-oriented data in this multi-method assessment, a wider range of processes could be uncovered and analyzed in detail (Caldwell & Leslie, 2010; Scott, 2008). The present study more particularly went beyond prior research as it explicitly included the schematizing process, an under investigated research area at the moment. Therefore, it must be viewed as a first explorative attempt to uncover pre-adolescents' dynamic schematizing phases and (meta)cognitive processes by means of pen movement analysis. This study hopes to open more windows onto more process-oriented approaches for the in-depth study of GS construction by means of a digital writing pen.

Results from this study underline the importance of orienting students at the very earlier stages towards learning from text and initiating text-learning strategy use in general and schematizing skills in particular from late elementary school on. Researchers can apply the developed protocols and rubrics in future research to uncover the relationship between text-learning strategies and a comprehensive range of measures (e.g., recall measures, verbal and spatial ability tests, self-report inventories, eye-tracking, or retrospective interviews) (Alamargot et al., 2010; Winne, 2010). A final aspiration of this study is encouraging longitudinal intervention studies to asses changes in text-learning strategy use, strategy repertoires, and schematizing skills over time. This can inform educational practice on how to effectively develop and stimulate a solid strategy base enabling students to strategically and effectively engage in text-based learning.

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Appendix

Text-learning strategy protocol

	Example excerpt from the think-aloud transcripts	Code
Overt cognitive text-learning strategies		
Text-structuring		
Simultaneously reading and highlighting	The student simultaneously reads and highlights the text information.	1
Indicating relevant information for highlighting	*'I am going to mark this word because I think it is important.'*	2
Marking text sentences	The student marks text sentences.	3
Marking key words or key sentences	The student marks key words or key sentences.	4
Marking titles and subtitles	The student marks titles or subtitles.	5
Marking figures	The student marks figures.	6
Using different colors	The students uses different colors to mark the text.	7
Scratch paper noting		
Instant linear summary	The students start immediately with a linear summary without reading the text first.	8
Rereading for schematizing	*'First, I read this and then I copy the most important words on my scratch paper'*	9
Linear summary – key words	The student copies key words on the scratch paper.	10
Linear summary – key sentences	The students copies key sentences on the scratch paper.	11
Linear summary – paraphrasing text	The students paraphrases the text and writes it down on the scratch paper.	12
Linear summary – structuring scratch paper	*'This is the summary of the first part (student draws a line underneath).'*	13
Graphical summary	The students graphically summaries the text information on the scratch paper.	14
Covert cognitive text-learning strategies		
Studying pictures		
Explicitly studying pictures	*'I am going to look at the picture now.'*	15
Relating pictures to text information	'(In the text) *So the female and male sea horse have different chests.* (In the picture*) O yes, I can see the sea horse on the picture is a boy!'*	16
Elaboration		
Activating prior knowledge	*'I saw sea horses before and their head looks like the head of a horse.'*	17
Relating prior knowledge to the text	*'Sea horses have no ribs. I didn't know that!'*	18
Imagining text information	*'The biggest sea horse can be 30 centimetres. That's about as long as my ruler.'*	19

Scratch paper learning		
Retelling scratch paper by heart	The student retells scratch paper by heart.	20
Rereading scratch paper	The students rereads the scratch paper.	21
Covering up scratch paper	*'I am going to cover up the scratch paper and retell the information on it by heart.'*	22
Copying text information	The student copies text information on the scratch paper to learn the text.	23
Rereading or retelling the text		
Rereading for memorizing	The students rereads the text for memorizing.	24
Rereading with emphasis on certain keywords	*'So the largest sea horse is (with emphasis) thirty centimetres.'*	25
Literally retelling	The student literally retells the text information.	26
Scanning or retelling highlighted information	*'I am going to read my marked sentences again.'*	27
Covering text information and literally retelling it	The student covers up the text information and retells it literally.	28
Paraphrasing	*'Sea horses do not have any ribs, but they do have a dorsal fin.'*	29
Memorizing pictures	Student covers up the pictures and tells by heart: *'So this is the spinal column and this the dorsal fin'*.	30
Covert metacognitive text-learning strategies		
Text orientation		
Scanning the text before reading	Student scans the text before reading.	31
Reading the whole text before learning	Student reads the whole text at once.	32
Monitoring		
Checking progress	*'So this is what I have already done and this is what I have to do next'*	33
Rereading difficult words	Student rereads difficult word.	34
Stating incomprehension	*'I don't understand this… Sticklebacks are that fishes too?'*	35
Stating comprehension	*'Ok, now I understand.'*	36
Difficulty with text content	*'The scientific name is Hippocampus. That's a difficult name…!'*	37
Self-evaluation		
Verifying in the text	*'Sea horses can live in all oceans I think. I'll check in the text if this is correct'.*	38
Structuring scratch paper to verify what is learnt	*'I am going to indicate with a marker on my scratch paper what I have to learn again.'*	39
Inserting intermission to rehearsal	*'Wait… I am going to retell this again.'*	40
Self-questioning	*'Where do sea horses live?'*	41
Rehearsal by heart	The students rehearses the text information by heart (at the end of the learning task).	42
Noticing memory failure	'Sea horses live in all oceans nearby … Hmm, I don't know this anymore…'	43
Covert motivational text-learning strategies		
Motivational statements	*'I find the topic of the text interesting.'* *'I think I am doing well in learning the text.'*	44

4 Learning from text in late elementary education. Comparing think-aloud protocols with self-reports.

This chapter is based on:

Merchie, E., & Van Keer, H. (2014). Learning from text in late elementary education. Comparing think-aloud protocols with self-reports. In Z. Bekirogullari (Ed.), Procedia Social and Behavioral Sciences (Vol. 112, pp. 489–496). doi: 10.1016/j.sbspro.2014.01.1193

Chapter 4
Learning from text in late elementary education. Comparing think-aloud protocols with self-reports.

Abstract

Although measuring pre-adolescents' text-learning strategy use with self-report inventories is most convenient for large-scale research, their use is accompanied with some concerns and their validity has been criticized. This study compares two different measurement methods (i.e., self-report and think aloud). More specifically, the relationship between subscale and item scores of the Text-Learning Strategies Inventory and the occurrence of the corresponding coded behavior in students' think-aloud protocols is studied. Moderate to high correlations were found for the subscales reflecting overt and covert cognitive text-learning strategies. Uncovering the relation between metacognitive self-reported and observed strategy use was more difficult.

Introduction

Text-learning strategies

Students are gradually confronted with more informative texts when progressing through their educational carrier, as they are increasingly used in classroom practice to reach instructional objectives (Schellings & Broekkamp, 2011). Therefore, equipping students with the necessary strategies for text-based learning arises as an important educational goal in late elementary education. Text-learning strategies encompass many individual learning techniques (e.g., highlighting, rereading) that promote students' text processing (i.e., selection and organization of text) and text learning (i.e., integration and recall of text information) (Merchie, Van Keer, & Vandevelde, 2014; Wade, Trathen, & Schraw, 1990). From a broad self-regulated learning perspective, these strategies are in essence either cognitive (e.g., organization), metacognitive (e.g., monitoring), or motivational (e.g., self-efficacy) in nature (e.g., Pintrich, 2004; Weinstein, Jung, & Acee, 2011; Weinstein & Mayer, 1986). Some text-learning strategies can be executed overtly, making them easily observable (e.g., text-noting techniques, such as summarizing), whereas others are applied more covertly (e.g., mental learning techniques, such as paraphrasing or mentally rehearsing text) (Wade et al., 1990). Finding an appropriate way to map and gain insight into those strategies at the early stages of strategy development is important, not only to orient strategy instruction towards students' spontaneous study activities (Pressley & Harris, 2006), but also to register students' strategy repertoire evolution throughout a longer time span.

Measuring text-learning strategies: Think-aloud protocols versus self-reports

Many attempts have been made in the literature to measure learning strategies in various contexts with different data gathering methods (Schellings, 2011; Scott, 2008). Two methods are specifically related to learning from text. First, think-aloud methodology has been frequently applied (e.g., Fox, 2009; Greene, Robertson, & Croker Costa, 2011). Here, data are gathered on-line during task execution as learners are asked to verbalize all their ongoing actions and thoughts (Scott, 2008). In this way, text processing and learning activities are directly revealed without delay and are expressed in students' own wordings. Afterwards, the verbalizations are transcribed by the researcher into a think-aloud protocol (TAP), which is subsequently coded with a TAP-coding instrument. The occurrence of the coded categories are used afterwards for analysis purposes. Using the think-aloud method is, however, also associated with some concerns. For example, elementary school children may find thinking aloud very demanding due to their verbalization skills, concentration, or reactivity. It could also influence their strategic actions (i.e., they might process the text differently) or affect their later recall (Caldwell & Leslie, 2010).

Second, also task-specific self-report instruments can be used to gain insight into students' strategy use during learning from text (e.g., Samuelstuen & Braten, 2007; Schellings & Van Hout-Wolters, 2011; van Hout-Wolters, 2009). Here, data are gathered off-line, as students are asked to report on their strategy use after they have finished a certain learning task. More specifically, they are asked to rate the degree to which they executed the mentioned learning activity on a Likert-scale. This method can be advantageous as opposed to thinking aloud during studying as the completion of the inventory items implies less cognitive demands. Furthermore, students are able to complete the inventory at their own pace and are not disturbed by the researcher, which occasionally prompts students to keep on verbalizing their thought processes during the thinking aloud process.

The above mentioned description makes clear that both methods for mapping students' text-learning strategy use are associated with some advantages and disadvantages, which are more extensively discussed in various other studies and are briefly enumerated in Table 1 (Braten & Samuelstuen, 2004, 2007; Caldwell & Leslie, 2010; Schellings, 2011; Schellings, van Hout-Wolters, Veenman, & Meijer, 2012; Scott, 2008; van Someren, Barnard, & Sandberg, 1994; Veenman & Alexander, 2011; Young, 2005). Based on the mentioned disadvantages, the validity of both measurement methods could be questioned. However, especially the use of self-report measures has most often been criticized in the literature, as they merely contain students' own perceptions about their strategy use, which might differ greatly from their actual behavior (Braten & Samuelstuen, 2007). To address this recurring concern, previous studies have tried to explore the correspondence between self-report inventories and think-aloud measures to substantiate their validity (e.g., Schellings, 2011; Schellings et al., 2012). In this respect, this study focusses on the correspondence between two data gathering methods both aiming at measuring pre-adolescents' spontaneous text-learning strategy use, i.e., by means of on-line thinking-aloud and off-line self-report.

Table 1

Overview of the main advantages and disadvantages of off- and on-line measurement methods

Advantages	Disadvantages
Off-line methods (e.g., self-reports)	
• Less intrusion into the normal thinking. • Cognitive demands are reduced. • Learners are more focused on the content and not disturbed or influenced by interaction with the assessment administrator. • Straightforward and efficient data gathering and scoring in large samples.	• Memory-reconstruction problem: Unawareness of or forgotten executed learning activities. • Prompting effect: Questions in the inventory may distort retrospective self-reports. • Items problems: Abstract wording, understandability. • Reading proficiency and social desirability can confound reliability.
On-line methods (e.g., think-aloud)	
• Uncovers thought processes and reveals the content of working memory. • Data are gathered directly without delay. • The learner does not give thought-interpretations and is not required to bring them into a predefined form. • Reduces memory failure.	• Ability and reactivity to verbalize thought processes can compromise assessment. • Verbalization stops can disrupt comprehension. • Time and labor insensitive analysis, not easily usable or efficient with large samples. • Can influence strategic action or later recalls. • Data-incompleteness: Learners can edit or omit thoughts that come to mind.

Method

Participants

Twenty fifth and sixth-grade students (13 girls and 7 boys) took part in this study. Students were aged between 10.92 and 12.67 with a mean age of 11.84 (*SD*=0.62). Only one student had a different home language than Dutch. Students with varying achievement levels were selected to assure the sample was representative.

Instruments

Learning task

Students spontaneous text-learning strategy use was assessed individually by means of a learning task. Students were instructed to study a 300-word informative text entitled 'the wonderful life of sea horses' in their own way while thinking aloud. Beforehand they had a practice session in thinking aloud to familiarize them with the method (van Someren et al., 1994). The informative text was subdivided into three text paragraphs, each accompanied with a subtitle and a picture. During studying, students were allowed to make notes in any way they desired, but they were not obligated to do so.

TLSI-subscales

Immediately after text-learning the Text-Learning Strategies Inventory (TLSI) was administered. In this respect, both a think-aloud and a self-report measure were compared in one research design. The 37-item inventory was developed and validated in previous cross-sectional large-scale research (Merchie et al., 2014). The TLSI consists of nine subscales: summarizing and schematizing (Cronbach's α=.88), highlighting (single-item scale), rereading (α=.74), paraphrasing (α=.72), linking with prior knowledge (α=.71), studying titles and pictures (α=.69), planful approach (α=.58), monitoring (α=.60), and self-evaluation (α=.71) (Merchie et al., 2014). The reliability of the full instrument in this study was acceptable (α=.74). In the present study, some subscale reliabilities were rather moderate to low (see Table 3), probably due to the small sample size. The TLSI reflects overt (e.g., schematizing activities) and covert (e.g., mentally paraphrasing), as well as cognitive (e.g., organization) and metacognitive (e.g., comprehension checking) text-processing and learning-activities. The inventory is task-specific as the included items specifically refer to the just accomplished learning task (Samuelstuen & Braten, 2007). Students were instructed to silently complete the inventory at their own pace after studying the text, rating to which degree they applied the specified learning activities in the inventory.

TLS-frequencies

The twenty think-aloud protocols were analyzed by means of the Text-Learning Strategy protocol (TLSP) (Merchie & Van Keer, 2014), which had a highly acceptable interrater reliability (Krippendorff's α = .91) (Hayes & Krippendorff, 2007). The coding instrument encompasses forty-three different subcategories representing both text-processing (i.e., to select and organize textual information) and text-learning activities (i.e., to acquire the text information). All subcategories are classified within eleven main categories reflecting, in accordance to the TLSI-subscales, both overt and covert, cognitive and metacognitive text-learning strategies.

Data-analysis

For data analysis, the inventory subscales or items were matched to the corresponding TLSP main or subcategories. Following Schellings et al. (2012), the nonparametric correlation Spearman's rho was used to calculate the correlation between the TLSI-subscales and the corresponding TLSP-frequencies. As in some cases, there was only a direct relationship between a single inventory-item and one individual coding category in the TLSP, an item-level comparison was made. For this analysis, Kendall's tau was used.

Results and discussion

In a first step, the TLSI-subscales were matched to the corresponding TLSP-categories In this respect, three matching methods were applied. First, some TLSI-subscales could be immediately matched to whole main categories (matching method 1). For instance the TLSI-subscale 'summarizing and schematizing' was matched to the two main TLSP-categories 'scratch paper noting' and 'scratch paper learning', consisting of several subcategories (e.g., making a linear summary, making a graphical summary, rereading scratch paper, covering up scratch paper). Second, other TLSI-subscales were matched to the accumulation of various subcategories (matching method 2). This is for instance the case for the TLSI-subscale 'linking with prior knowledge'. The main TLSP-category 'elaboration' consisted of three subcategories: 'imagining text information' ,'activating prior knowledge', 'relating prior knowledge to the text'. However, only the last two TLSP-subcategories could be explicitly linked to the inventory subscale 'linking with prior knowledge'. Therefore, only the frequencies of those two categories were taken into account into the analyses. A third possibility was matching individual TLSI-items to individual TLSP-subcategories (matching method 3). This was for instance the case for the metacognitive subscales, as only two inventory items were reflected into the think-aloud coding categories. The TLSI-subscale 'self-evaluation' was not included in the comparison, as no corresponding coding category was found in de TLSP. In total, 968 units (89.63%) of the 1080 total coded units matched directly to the TLSI-subscales and were included into the comparison. Table 2 shows some examples of the three matching methods. Table 3 presents the descriptive information and the correspondence between the TLSI and TLSP .

In a second step, correlations were calculated between the inventory subscales and the corresponding TLSP-frequencies. The correlation between the inventory and think aloud measures on the subscales 'summarizing and schematizing' (r= .78, p<.001), 'highlighting' (τ = .50, p=.004), 'rereading' (r=.69, p<.001), 'paraphrasing' (r=.50, p=.037), 'linking with prior knowledge' (r=.52, p=.003), and 'studying titles and pictures' (r=.63, p=.001) were modest to strong and all reached significance. This is a promising finding, providing evidence for the validity of pre-adolescents' self-reported cognitive overt and covert text-learning strategies. This finding is in agreement with previous research that also found promising positive correlations between self-reported learning activities and think-aloud measures (Schellings, 2011; Schellings et al., 2012). Future research could also take into account the examination of trace data (i.e., the observable data students produce during learning from text) to support the validity of the self-reported overt text-noting strategies (i.e., 'summarizing and schematizing' and 'highlighting') (Braten & Samuelstuen, 2007).

Table 2

Examples of the inventory items of the TLSI and corresponding TAP-fragments

TLSI-subscale	Matching method	TLSI-item	Corresponding TAP-fragment
Cognitive strategies			
Overt			
Summarizing and schematizing	1	I wrote down the most important information	'First, I will read this and then copy the most important words on my scratch paper'
Highlighting	1	I marked the most important things	'I am going to mark this because I think it is important'
Covert			
Rereading	1	To learn the text, I read the text a lot of times	'I am going to reread this once again'
Paraphrasing	2	I tried to repeat the text in my own words	After reading the information on the sea horse's physique, the student paraphrases: 'Sea horses do not have any ribs, but they do have a dorsal fin'
		I stopped once in a while to repeat	'Wait… I'm going to retell this again'
Linking with prior knowledge	2	I thought about what I already knew about sea horses	'I saw sea horses before and their head looks like the head of a horse'
Studying titles and pictures	2	I looked at the pictures to remember the information	Students covers up the body part-picture and tells 'so this is the spinal column and this is the fin'
Metacognitive strategies			
Covert			
Planful approach	3	First, I read the whole text and then I started learning	'First, I'm going to read the text'
Monitoring	3	While learning, I checked what I had already done and how much I still had to do	Student checks during learning the length of the text
Self-evaluation	/	I managed to learn the text in a good way	/

In contrast with the significant correlations found for the cognitive text-learning strategies, low and non-significant tau-correlations were found for the items concerning 'planful approach' (i.e., reading the whole text before learning) (τ =-.255, p=0.116) and 'monitoring' (i.e., checking progress) (τ =.238, p=.123). With regard to 'planful approach' the item-mean of 3.95 shows that the majority of the students indicated that they have read the text before learning. However, after inspecting the think-aloud protocols, only one fifth of the students actually engaged in this activity. One possible explanation is that students may have forgotten they did not perform this activity (i.e., memory-reconstruction problem) (Veenman, 2011), assuming they have read the text (parts) before starting any text processing or acquiring activity. Another possible explanation is that the inventory item is interpreted differently by the students than it was intended by the researcher. In this respect, it would be interesting to interview students about their interpretation of the inventory items (Karabenick et al., 2007). Furthermore, the low correlation regarding the monitoring progress activity was not surprising, as this behavior was only counted once in the think-aloud protocols.

Table 3
Descriptive information on the self-report and think-aloud measure

TLSI-subscale	Text-Learning Strategies Inventory (TLSI) *N* items (*N* items included in comparison)	*M* (*SD*)	Cronbach's *α*	Text-Learning Strategy protocol (TLSP) *N* corresponding TLSP subcategories	Frequencies (percentage)
Cognitive strategies					
Overt					
Summarizing and schematizing	7 (7)	2.84 (1.18)	.90	11	380 (35.18%)
Highlighting	1 (1)	3.05 (1.70)	/	7	149 (13.80%)
Covert					
Rereading	3 (3)	3.23 (1.03)	.74	2	108 (10%)
Paraphrasing	7 (7)	3.09 (.61)	.58	6	256 (23.70%)
Linking with prior knowledge	3 (3)	3.08 (.88)	.74	2	20 (1.85%)
Studying titles and pictures	3 (3)	3.92 (.90)	.39	2	39 (3.61%)
Metacognitive strategies					
Covert					
Planful approach (scale) (single item)	3 (1)	3.52 (.68) 3.95 (1.32)	.61	1	15 (1.39%)
Monitoring (scale) (Single item)	5 (1)	3.09 (.55) 3.00 (.97)	.47	1	1 (0.09%)
Self-evaluation	5 (0)	3.97 (.44)	.58	0	0 (0%)

Note. The percentages of the TLSP-frequencies are based on the 1080 total coded units in the protocols. In this respect 968 coded units matched directly to the TLSI-subscales and 112 coded units were left out of consideration.

Further investigation is needed to explore the relationship between self-reported metacognitive text-learning strategy use and actual behavior more in depth. Several inventory-items from the metacognitive subscales were not included into this comparison as no corresponding TLSP-categories were found. For example, two students rated the item 'While learning, I asked myself: Do I still have enough time?' (monitoring subscale) with a 4, indicating that they have executed this activity at a rather high frequency. However, this was not reflected in their think-aloud protocol. Here, it might be possible that they actually considered the time during studying but did not verbalize these thoughts or they could not make an accurate reflection upon this activity. Furthermore, the metacognitive subscale 'self-evaluation' was not included in this comparison as no corresponding behaviors were found. This might be due to the inventory items, which rather generally refer to the overall learning process (e.g., 'While learning, I managed to stay attentive and concentrated' and 'I managed to learn the text in a good way'). In addition, it can be hypothesized that these kind of verbalizations are less spontaneously expressed. Other measurement methods (e.g., retrospective interviews) could allow a more in-depth study of student's self-evaluation and furthermore of more motivational text-learning strategies, which were not included in this study.

This study also encountered some of the above mentioned advantages and disadvantages of both applied methods. It however also illustrates their complementarity. For example, not all coded units could be explicitly matched to the inventory items. The TAP-coding instrument is more extensive, comprising more than forty subcategories, including specific coding categories for activities which were executed by only a few students or at a very low frequency. This allows a more fine-grained analysis. The inventory data on the other hand, documents a more general picture of the commonly used text-learning strategies in late elementary education. It furthermore allows us to gain insight into more general learning processes which are not always immediately reflected into the think-aloud processes.

In conclusion, this comparison study provides evidence for the validity of the overt and covert cognitive strategy use in the Text-Learning Strategies Inventory. In this respect, the TLSI provided an acceptable alternative for the more time and labor-intensive think-aloud methodology. It is advised to complement the self-report data in future research with trace analysis. Further, multi-method research should be encouraged as examining the correlation between self-reported metacognitive strategy use and observed use was more difficult.

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5 Schematizing and processing informational texts with mind maps in fifth and sixth grade

This chapter is based on:

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Chapter 5
Schematizing and processing informational texts with mind maps in fifth and sixth grade

Abstract

From the age of 11-13, children start to spend increasingly more time on learning from texts. The need arises to support them in dealing with this text information and engaging them in self-regulated learning (SRL). This study is embedded within the cognitive component of SRL and focuses on mind mapping as a promising organizational learning strategy. Notwithstanding the fact that mind map skills are already important in middle grades, few studies have specifically addressed this concern. The following research questions were addressed: What is the impact of a ten-week intervention on students' (1) application of mind map rules and (2) processing of textual information? Data were collected by means of a repeated measures design (pretest, intermediate test, and posttest) in fifth- and sixth-grade classes (N = 62 students). The results reveal a significant evolution in students' application of mind map rules. Further, students improve significantly in processing the content of textual information in a mind map in a structured and relevant way. The findings of the present study demonstrate that fifth- and sixth-grade students are able to learn to process informative texts by means of an explicit mind map training intervention of ten successive weeks. Based on these findings, suggestions for future research are discussed.

Introduction

Currently, students are continuously being challenged by the exponential knowledge increase in our information society. As such, skills and strategies are required for realizing efficient and effective processing and acquisition of information (Crick, 2007; Seyihoglu & Kartal, 2010). To support students in this domain, education should develop active learners, learning independently and constructively (Boekaerts, Pintrich, & Zeidner, 2000; Cornford, 2002). In this respect, the concept of self-regulated learning (SRL) has recently played an important role in educational research, illuminating the learner's ongoing learning processes (Black, McCormick, James, & Pedder, 2006). SRL can be defined as a planned and cyclical way of regulating thoughts, feelings, and actions to meet personal goals (Boekaerts et al., 2000; Zimmerman & Schunk, 2001) and includes a motivational, metacognitive, and cognitive component (Winne & Perry, 2000). The motivational component concerns students' reasons for performing a task, whereas the metacognitive component refers to strategies for planning (e.g., setting goals), monitoring (e.g., monitoring comprehension), and modifying cognition (e.g., rereading text when comprehension fails) (Pintrich, 2004). The cognitive component of SRL encompasses learning strategies and tactics students can apply to effectively process and acquire new information (Perels, Gürthler, & Schmitz, 2005; Pintrich, 2004). The development of learning strategies can facilitate the process of learning from texts and can help students to select, organize, integrate, and recall subject matter (Warr & Downing, 2000; Weinstein & Mayer, 1986). These strategies become increasingly important, especially from the age of 11-13, when students have to spend more time independently on learning from texts and obtain information from them (Bakken & Whedon, 2002; Rawson, 2000). As a result, the focus at this age shifts from learning how to read and early reading skills to 'reading to learn' (Bakken & Whedon, 2002; Harlaar, Dale, & Plomin, 2007). In this respect, researchers call for approaches supporting children in learning texts, starting with processing those texts in a structured way by structuring and summarizing the large amount of text information (e.g., indicating keywords, marking and outlining main ideas) (Guastello, Beasley, & Sinatra, 2000; Novak, 2002). Therefore, the present study is embedded within the cognitive component of SRL, focusing on how we can help students in processing textual information.

Using graphic organizers as an organizational learning strategy

Generally, the basic learning strategies reported in the literature are rehearsal, elaboration, and organization strategies (Weinstein & Mayer, 1986; Weinstein, Husman & Dierking, 2000). A specific organizational strategy to help students process, structure, and acquire textual information is working with graphic organizers (GO) (Dansereau & Simpson, 2009; Vekiri, 2002). Stull and Mayer (2007) specify graphic organizers as spatial arrangements of words (or word clusters) to represent the conceptual organization of a text. They can clarify the relationship between important concepts in a text and illuminate big ideas (Banikowski, 1999; Crawford & Carnine, 2000). In this way, they can help students deal with the large amounts of information they are confronted with.

Several general theories underpin the use of GO. The Dual Coding Theory (Paivio, 1991) builds upon two sets of independent and separate systems for processing and storing information: a verbal and a non-verbal system. By using GO, the learner is capable of making associations between the visual and verbal material which facilitates information recall. A second important theory underpinning the use of GO is the Cognitive Load Theory (Sweller & Chandler, 1994; Sweller, van Merriënboer, & Paas, 1998). Here, a distinction is made between the limited working memory and an effective long-term memory in which large amounts of information can be stored. The load of the working memory can be reduced by adding GO to texts. Thirdly, the Visual Argument Hypothesis (Waller, 1981) assumes that the benefits of visual representations result from the spatial characteristics of a map. Those characteristics communicate the complex text content more efficiently because the processing of a map requires less mental efforts in working memory. In sum, these theories point to advantages of both verbal and spatial storage of subject matter, decrease of cognitive load, and simplification of complex relationships and ideas in texts by using GO.

Mind maps as a specific type of GO

A type of GO enclosing all the key components of the definition of Stull and Mayer (2007) is a mind map (Buzan, 1974, 2005), which is the focus in the present study. In a mind map, one key concept, often represented as an image, is located at the middle of the page. From this central topic, several related main topics are radiated out in the shape of thick branches. Attached to these main branches, other smaller branches represent related concepts. In this way, related words are associated through curved main and sub-branches. Mind maps can be further enriched by colors, images, codes, and dimension to reflect personal interest and individuality (Buzan, 2005).

The (effectiveness of) the specific characteristics of a mind map are grounded in and supported by research findings from both educational as well as brain research. The characteristics are based upon research investigating and supporting the advantages of the use of association (Budd, 2004; Haber, 1970; Mento, Martinelli, & Jones, 1999) and the effectiveness of connecting images to words and using color (Anderson & Hidde, 1971). The latter also stimulates creativity (Mento et al., 1999; Michalko, 2003) instead of working in a traditional way (e.g., linear thinking, taking notes in one color on lined paper). Furthermore, mind maps also incorporate the gestalt principles 'equality' (visual nearness of information by using colors and shapes) and 'proximity' (grouping of related elements) which promotes the faster identifying, processing, and storing of information (O'Donnell, Dansereau, & Hall, 2002; Wallace et al., 1998). All these findings are translated in a set of mind map rules (e.g., promoting association by using curved lines, thicker and thinner branches, capitals and small letters, incorporating colors, shapes and images, grouping associated key words) which should be carefully respected since they reflect the basic characteristics determining the effectiveness of mind mapping (Buzan, 2005).

Mind mapping and text processing

Both the specific characteristics of mind maps as the previously mentioned theories underpinning the use of GO give reason to believe that mind maps can help students in processing and learning those large amounts of information they meet in textbooks. At present, several studies indicate that mind maps are effective in helping students structure and summarize subject matter (Brinkmann, 2003; Farrand, Hussain, & Hennessy, 2002; Mento et al., 1999) and consequently in stimulating the cognitive component of self-regulated learning. Consequently, mind mapping as an organizational strategy seems promising in processing and schematizing texts. There are however several shortcomings in previously conducted research, we especially want to address in the current study.

First, few studies have investigated the effectiveness of mind mapping in middle grades. Research on GO and mind maps generally focuses on secondary and higher education, although the importance of the acquisition of processing skills in earlier grades is frequently stressed

(Guastello, Beasley, & Sinatra, 2000; Rawson, 2000). Furthermore, in regard to other studies on graphic organizers (e.g., concept mapping), studies on mind mapping have received far less recognition (Eppler, 2006).

Second, when studying the effectiveness of mind mapping in middle grades, it is a prerequisite to know whether children of this age group are already capable of making mind maps from an informative text. Are they already able to draw a mind map applying the mind map rules, to select the most important and relevant key words from a text and associate them in a correct manner? Almost no information is available about the mind map skills of middle grade children. Notwithstanding the fact that those skills are already important in middle grades, few studies have specifically addressed this concern.

This brings us to the third important concern about how to gradually learn children to mind map an informative text. Researchers within the existing literature are concerned about the training of mapping skills, which can be very time consuming (Hilbert & Renkl, 2008; McCagg & Dansereau, 1991). There is still little research information available, however, how to gradually learn children the efficiently and effectively structural processing of informative texts with mind maps in classroom practices. Further, special attention in the training has to be drawn explicitly to take into account the specific characteristics of mind maps, which have often been neglected in the limited number of mind map studies available. This can lead to a biased view on the effectiveness of mind mapping.

Research questions

Based on the promising role of mind mapping in supporting children in processing and schematizing texts and the different concerns regarding actual mind mapping research, two main research questions are addressed in the present study:

1. What is the impact of a mind mapping intervention on students' application of the mind map rules?
2. What is the impact of the intervention on students' processing of textual information (i.e., selecting relevant key words and making meaningful associations reflecting the complete text content) by using mind mapping?

With the first research question, we focus on whether mind mapping can be learned by middle grades students in a relatively short period of time by means of a ten-week intervention. We investigate whether children improve significantly in making a good mind map of an informative text by applying the mind map rules (Buzan, 2005). The second research question may shed a light on whether mind mapping can be considered as a potential organizational learning strategy to support middle grades school children in efficient and effective text processing and thus optimizing the cognitive component of SRL.

Method

Design

A repeated measures design (pretest, intermediate test, and posttest) was applied to evaluate the impact of a ten-week mind mapping intervention in authentic classes. The three tests were administered at the beginning, middle and end of the first semester at the end of each lesson in week 1, week 6 and week 10 of the intervention.

Participants

A total of 62 middle grades students of fifth (n = 29) and sixth grade (n = 33) from the Flemish speaking part of Belgium participated in the study (4 classes from 2 different middle-class elementary schools). All students were native speakers of Dutch (the instructional language in Flanders). The sample consisted of 31 girls and 31 boys. All participants were between 10 and 12 years.

Intervention

Even though a training or instruction in the use of maps is a key factor in producing positive outcomes (O'Donnell et al., 2002), there is still no effective longitudinal training method available, especially none combining mind mapping and text processing for middle grades students. Therefore, a ten-session mind map training was developed based on theoretical and practical insights and existing publications (Buzan, 2004, 2005; Hoffman, 2001). In each training session the aim was to make a mind map of an informational text (through the deliberate selection of main ideas and related sub topics and presenting the relationships between them in a meaningful way). Texts from the regular school books were therefore used and adjusted. Whereas the first three lessons were dedicated to getting to know mind maps and completing unfinished mind maps with relevant key words and images, the following lessons students learned gradually to construct a mind map themselves by applying a step-by-step plan. In this way, the importance of the active construction, manipulation, and transformation of textual information into a mind map (Farrand et al., 2002; Guastello et al., 2000) was respected. In each lesson, mind map rules (e.g., using curved lines, thicker and thinner branches, capitals and small letters, colors, shapes and images) were emphasized and applied (Buzan, 2005). Each session focused on one specific facet of constructing mind maps from an informational text (e.g., visualizing relationships between key words from different branches). Finally, the last session was dedicated to exploring other mind map possibilities: making a mind map for homework planning, using a mind map in other subject areas (e.g., mathematics) or for preparing a school talk. Table 1 presents an overview of the mind map training and the specific focus during each session.

In line with the social cognitive theory of Bandura (Snowman & Biehler, 2003), the first lessons (getting to know mind mapping) were primarily dominated by modeling by the teacher and observation and imitation by the students. Further, during the construction of mind maps individual work, group work, and class discussions were implemented during the sessions. The sessions focusing on the making of mind maps demanded active involvement of the students (analyzing, revising, and working with the text) which stimulated the internalization of the mind map instruction. Regarding the procedure, the intervention was preceded by a formal meeting to inform school leaders and all involved teachers. The intervention took place during ten successive weeks (one lesson of 50 minutes per week given by the researcher in the presence of the teacher). All lessons took place during regular school hours in the regular classrooms during the lessons on social studies and science and reading comprehension.

Table 1
Overview of the mind map training

Week	1	2	3	4	5	6	7	8	9	10
Getting to know mind mapping										
Mind map rules	x	x	x	x	x	x	x	x	x	x
Reading a mind map and completing a mind map with relevant key words		x	x	x	x	x	x	x	x	x
Practicing the use of images, figures, and abbreviations within a mind map			x	x	x	x	x	x	x	x
Making mind maps										
Applying a step-by-step plan to build up a mind map				x	x	x	x	x	x	x
Making a good mind map within a marked out time span, clustering associated key words, visualizing relationships between keywords in different branches by means of arrows and connectors						x	x	x	x	x
Finding main branches, limit irrelevant information in the mind map, readability of the mind map							x	x	x	x
Mind mapping in other situations									x	x

Instruments

The pretest, intermediate test, and posttest consisted of independently making a mind map of an informative text within 30 minutes. For each measurement occasion a text of about 350 words was used. The texts were different as to the topic (respectively about the work and life of Leonardo da Vinci, Albert Einstein, and Pablo Picasso), but equivalent as to the structure and length. Texts were presented in the same order for every class. As the focus was on students' mind map skills, text comprehension problems were clarified by the teacher or researcher to reduce individual differences in text understanding. At the end of the intervention period and after the complete data collection (pretest, intermediate test, and posttest), the characteristics and quality of students' mind maps were scored in random order.

Since reliable scoring methods for mind maps in elementary education are very scarce, an analytic scoring rubric based on research literature on scoring GO was developed (Hilbert & Renkl, 2008; Lee & Nelson, 2005; Meier, Rich, & Cady, 2006; Nitko & Brookhart, 2007; Taricani & Clariana, 2006). In the rubric, the different components of a good mind map were identified and scored on a 4-point scale (Meier, Rich, & Cady, 2006; Taricani & Clariana, 2006). Hereafter, the developed rubric was presented to experts on SRL, text processing, reading comprehension and mind mapping on the one hand and elementary school teachers on the other hand to evaluate the developed rubric from an academic as well as a practice-based point of view. Based on their comments, the rubric was slightly modified. The final Mind Map Scoring Rubric (MMSR) (Appendix) contains two broad categories ('shape and organization' and 'content'). The subcategories in the category 'shape and organization' were identified based on the mind map rules (e.g., using a radial structure). By means of these subcategories, it is verified whether mind map rules are respected and which specific elements (e.g., images, colors, arrows, connectors) are integrated into the map. Within the main category 'content', relevant content elements (e.g., relevance of key words) are specified. These subcategories evaluate how much relevant key information is represented and linked to each other in the map.

In addition to the use of the MMSR, students' mind maps were compared to an expert map, based on a consensus among several experts, to verify whether students' mind maps covered the text content adequately. An overall score (between 0 and 10) was assigned to each mind map to represent the general quality of the mind map. Further, the number of relevant clusters (the encircling of large associated main and sub-branches) and the number of relevant main branches (i.e., main branches with a relevant and covering key word) were counted.

Data analysis

A total of 186 mind maps (3 measurement occasions for 62 participants) were scored by two independent trained coders by means of the MMSR. The second coder double scored respectively 24 mind maps per measurement occasion and was not aware of the order in which the texts were presented to the students. In this respect, 72 rubrics (39%) were double coded to check interrater reliability by means of Krippendorff's alpha (Hayes & Krippendorff, 2007). Krippendorff's alpha is a reliability coefficient that accounts for chance agreement. Krippendorff's alpha further takes into account the magnitude of the misses, adjusting for whether the variable is measured as nominal, ordinal, interval, or ratio. Inter rater reliability is determined by calculating the proportion of observed and expected disagreements between the raters. Table 2 presents the Krippendorff's alpha (α) interrater reliability coefficients of all subcategories in the MMSR. Krippendorff's alpha ranged from .67 to 1, indicating good to excellent agreement.

Table 2
Overview of the Krippendorff's alpha interrater reliability coefficients

Subscale	α
Shape and organization	
Thick main branches and thin sub-branches	1
Capitals on main branches and small letters on sub-branches	.85
Use of color	.84
Use of symbols, images, and abbreviations	.79
Use of arrows and connectors	.76
Readability	.75
Position of key words	.80
Radial structure	.83
Content	
Choice of key words	.73
Content coverage	.72
Associations	.67
Word choice on the main branch	.70
Additional characteristics	
Number of relevant clusters	.84
Number of main branches	.94
Number of relevant main branches	.87
Overall score (ranging from 0 to 10)	.80

The scores on the rubric were analyzed quantitatively by means of One-Way Repeated-Measures Analyses of Variance. Additionally, Post Hoc pairwise tests with Bonferroni correction were conducted to specify the differences between de measurement moments. All statistics reported in this study were calculated using SPSS version 17.0.

Results

Table 3 presents the average scores on the different subcomponents in the MMSR for each measurement occasion. Post Hoc pairwise comparison tests revealed significant differences between the measurement moments. These results are presented in Table 4.

The first aim of the study was to investigate whether children improve their mind mapping skills throughout the intervention. No significant evolution in the use of thin and thicker branches (F(2,58)=1.1851, p=0.166) and the use of symbols, images and abbreviations (F(2,58)=2.450, p=0.095) was observed. The results reveal several significant evolutions in using capitals on the main branches and small letters on the other branches (F(2,58)=8.754, p<0.001) and in the use of color (F(2,58)=5.609, p=0.006). Concerning the use of capitals and small letters, there is no significant evolution to any further extent between the intermediate and the posttest. Regarding the use of color, significant differences were found between posttest and pretest and between posttest and intermediate test. This was also the case for the readability of the mind map, the position of key words and the use of clusters and arrows to group and link information. The readability was significantly better at the end of the intervention (F(2,58)= 6.314, p=0.003). In this respect, Figure 1 and 2 illustrate a poorly and well readable mind map (see the readability and clearness criterion in the rubric in Appendix). Further, at the end of the intervention, keywords were more placed on the branches instead of next to the branches (F(2,58)=3.281, p=0.045) and children made significantly more clusters

(F(2,58)=5.979, p=0.004). An example of a cluster can be found in Figure 2 where the main branch 'perioden' and the sub-branches related to it are enclosed. In addition, more arrows were used to link information (F(2.58)=4.216, p=0.020). Finally, the radial structure of the mind map was also better respected (F(2,58)=11.238, p<0.001). Significant differences are revealed between all measurement moments. Figure 4 shows a mind map wherein the radial structure is respected, which is not the case in Figure 3 (see the mind map structure criterion in the rubric in Appendix).

The second aim of this study was to investigate whether children make significant progress in processing textual information by using mind mapping. Children used more textual information in the mind map (F(2,58)=82.990, p<0.001), as illustrated in Figure 5. Further, they chose more relevant key words on the sub-branches (F(2,58)=14.397, p<0.001), which are generally nouns and verbs. As a result, the length of the branches stayed relatively short (Figure 6). The words within a branch were better matched and associated (F(2,58)=10.390, p<0.001). The selection of key words on the main branches was significantly better (F(2,58)=14.397, p<0.001) as well. Moreover, the selected key words on those main branches were more relevant and covering (Figure 7). Concerning the choice of key words on the sub-branches and main branches, significant differences were found between all measurement moments. As to content coverage and the association of words within a main branch, no significant evolution was found between the intermediate and the posttest. The number of relevant main branches raised significantly (F(2,58)=46.298, p<0.001) and the children got better overall scores on their mind maps (F(2,58)=125.468, p<0.001).

Table 3

Average scores on the MMSR

	Pretest	Intermediate test	Posttest	*F*	*p*
Shape and organization					
Thick main branches and thin sub-branches	3.83	3.98	3.98	1.185	0.166
Capitals on main branches and small letters on sub-branches	3.07	3.52	3.58	8.754	0.000***
Use of color	3.82	3.62	3.98	5.609	0.006**
Use of symbols, images and abbreviations	1.80	2.03	2.27	2.450	0.095
Use of arrows and connectors	1.07	1.02	1.27	4.216	0.020*
Readability	3.03	3.28	3.57	6.314	0.003**
Position of key words	3.58	3.62	3.78	3.281	0.045*
Radial structure	2.85	3.17	3.48	11.238	0.000***
Content					
Choice of key words	3.12	3.43	3.63	14.397	0.000***
Content coverage	1.22	2.32	2.37	82.990	0.000***
Associations	2.95	3.28	3.42	10.390	0.000***
Word choice on the main branch	2.67	2.97	3.40	14.397	0.000***
Additional characteristics					
Number of relevant clusters	0.05	0.08	0.40	5.979	0.004**
Number of main branches	3.43	4.75	4.25	15.451	0.000***
Number of relevant main branches	2.25	4.07	3.88	46.298	0.000***
Overall score (ranging from 0 to 10)	2.72	5.59	6.38	125.468	0.000***

Note. *p < .05, ** p < .01, ***p < .001.

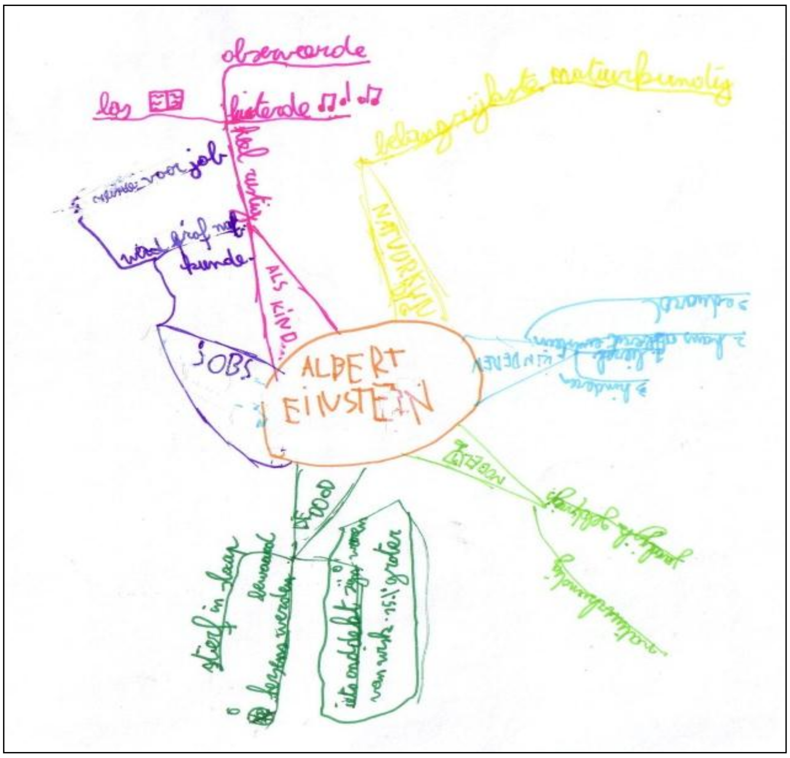

Figure 1. Example of a poorly readable mind map.

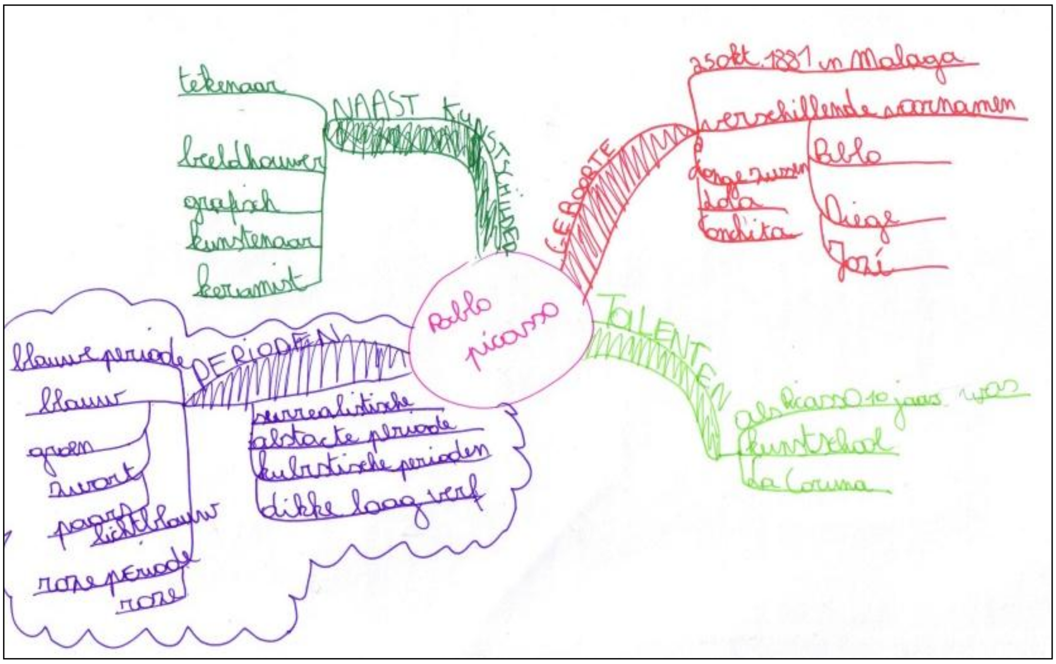

Figure 2. Example of a well readable mind map.

Figure 3. Example of not respecting the radial structure of the mind map.

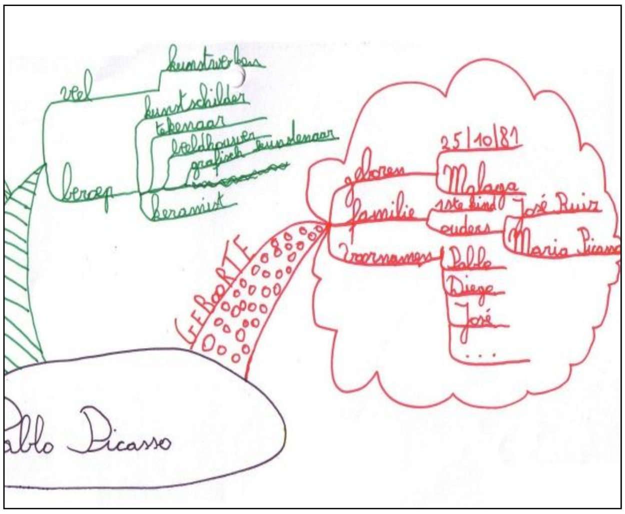

Figure 4. Example of the radial structure of a mind map.

Table 4

Results of the Post Hoc Pairwise comparisons on the MMSR

	intermediate test-pretest *p*	posttest-pretest *p*	posttest – intermediate test *p*
Shape and organization			
Thick main branches and thin sub-branches	n.s.	n.s.	n.s.
Capitals on main branches and small letters on sub-branches	0.000***	0.000***	n.s.
Use of color	n.s.	0.040*	0.003**
Use of symbols, images and abbreviations	n.s.	n.s.	n.s.
Use of arrows and connectors	n.s.	0.033*	0.006**
Readability	n.s.	0.001**	0.008**
Position of key words	n.s.	0.045*	0.024*
Radial structure	0.017*	0.000***	0.002**
Content			
Choice of key words	0.011*	0.000***	0.004**
Content coverage	0.000***	0.000***	n.s.
Associations	0.004**	0.000***	n.s.
Word choice on the main branch	0.000***	0.000***	0.001**
Additional characteristics			
Number of relevant clusters	n.s.	0.001**	0.003**
Number of main branches	0.000***	0.000***	0.027*
Number of relevant main branches	0.000***	0.000***	n.s.
Overall score (ranging from 0 to 10)	0.000***	0.000***	0.000***

Note. *p < .05, ** p < .01, ***p < .001.

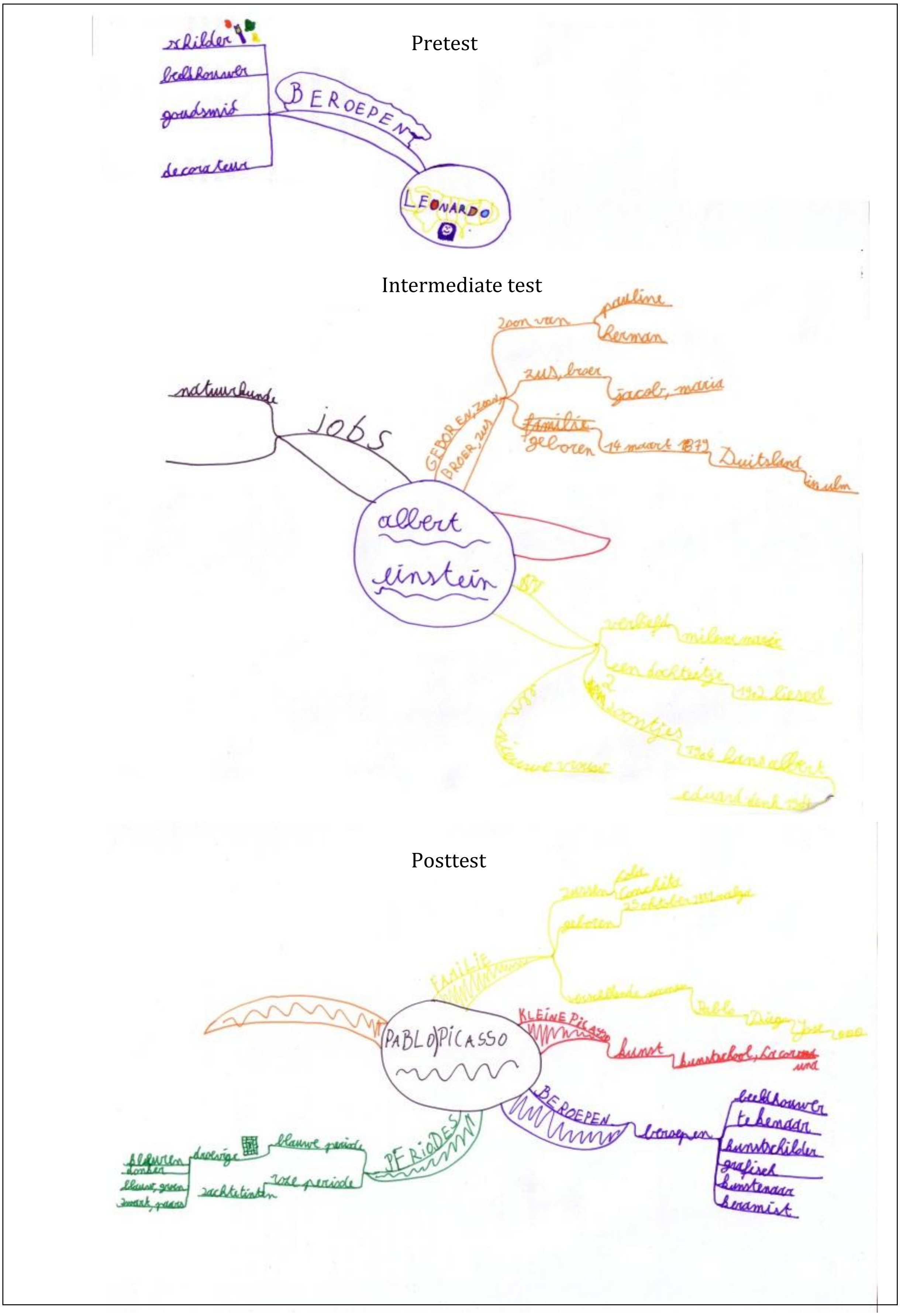

Figure 5. The use of more textual information in the mind map.

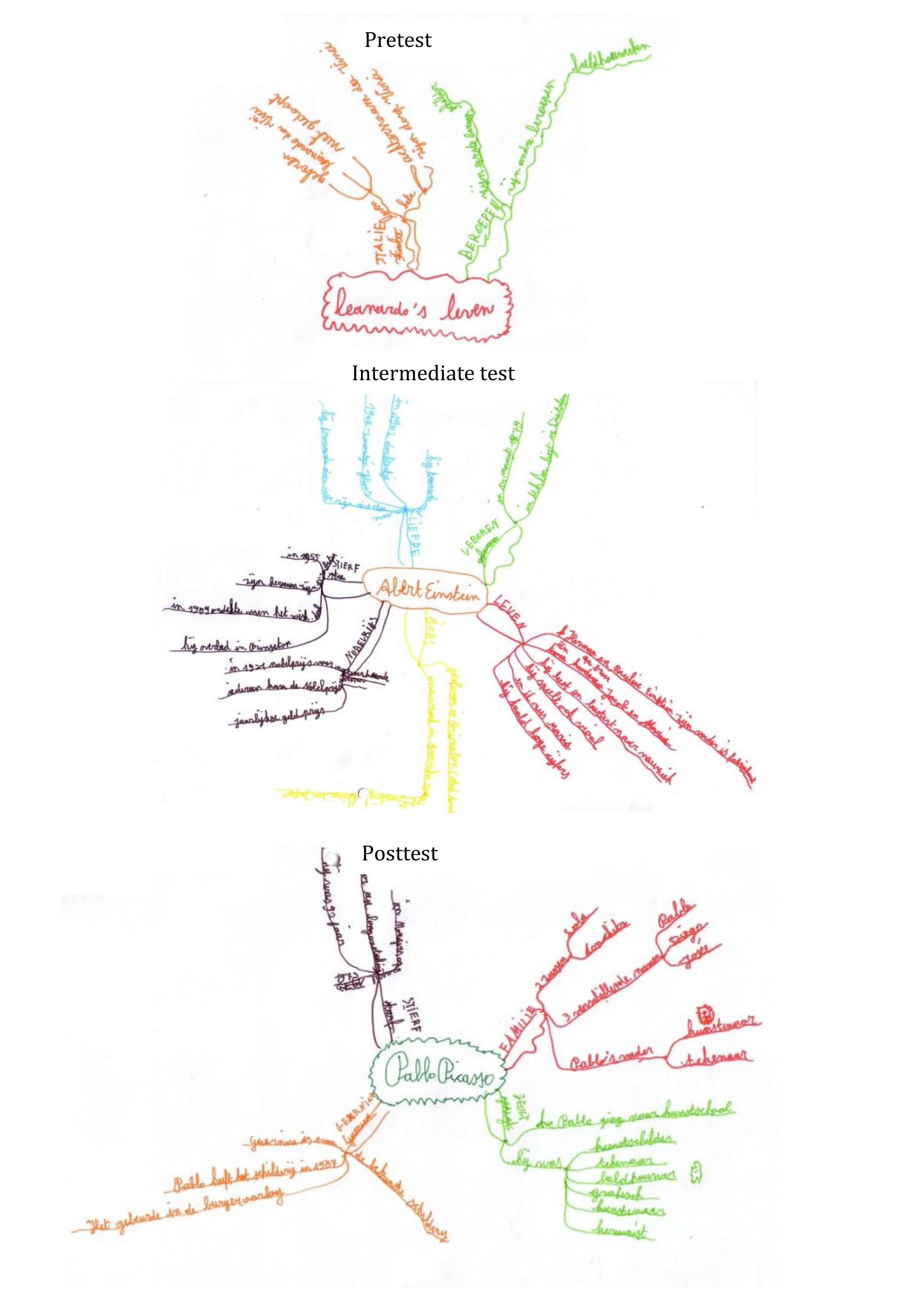

Figure 6. Example of the evolution of key words on a branch.

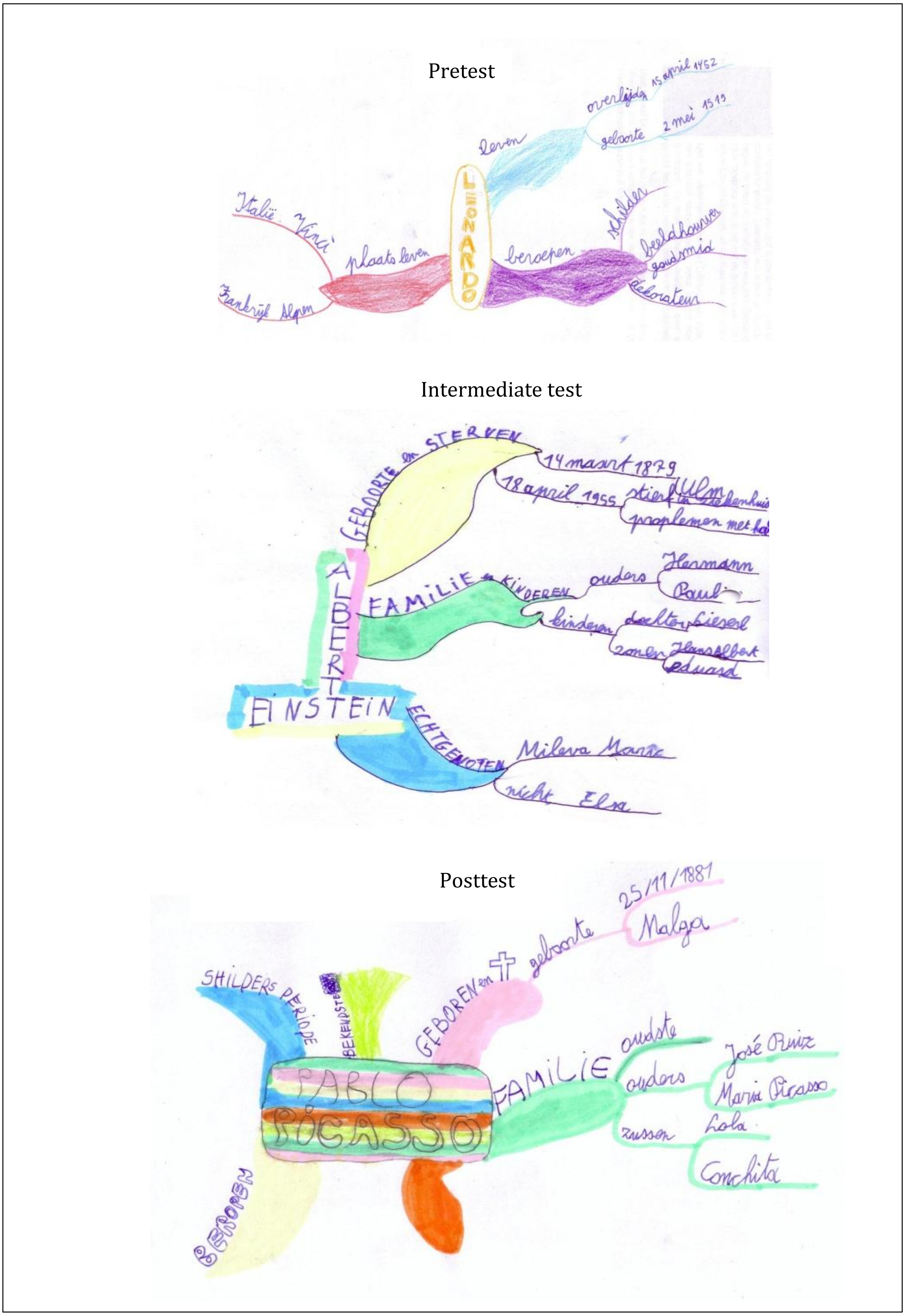

Figure 7. Example of the evolution of relevant key words on the main branches.

Discussion

The present study focused on text processing by means of mind mapping in middle grades. This study has investigated the impact of a ten-weeks mind mapping intervention on students' (1) application of mind map rules and (2) processing of textual information by using mind mapping.

Regarding the first research question, the present study reveals that on the majority of the subcategories of 'shape and organization' students progress significantly (i.e., using capitals on main branches and small letters on sub-branches, the use of color, arrows and connectors, readability, position of key words, radial structure). This is important taken into account the demonstrated effectiveness of the use of correctly made associations (Haber, 1970; Mento et al., 1999), dimension (Budd, 2004), color and images (Anderson & Hidde, 1971; Banikowski, 1999) and gestalt principles (O'Donnell et al., 2002). Two concerns however, should be taken into account. First, it is important to consider the fact that applying the mind map rules might provoke extra unnecessary cognitive load (Stull & Mayer, 2007), which can hinder deeper cognitive processing of the text and consequently meaningful learning (Novak, 2002).

Second, it is important to draw attention to the significant difference that was found in using arrows and connectors within the mind maps, since the children evolve from 'no use' to rather 'incorrect use'. Although understanding the relationships between ideas in a text is an advantage of using graphic organizers (Robinson & Skinner, 1996), the results of the present study indicate that it is not obvious for middle grades students to make these relationships explicit by themselves. Further, even though using images and symbols can stimulate the creativity and learning potential of the students (Crick, 2007; Mento et al., 1999; Michalko, 2003), the use of these elements was hardly observed in students' mind maps. Therefore, one should pay attention to the fact that when learning to mind map, this is not limited to learning to apply the mind map rules, whereby the search for connections and the critical reflection on ideas in a text becomes neglected (D' Antoni, Zipp, Olson, & Cahill 2010; Rawson, 2000).

As to the second research question, the results indicate that participants evolve significantly in processing a text in a mind map. The students choose better and shorter key words on the sub-branches, use more textual information in the mind map (content coverage), improve in making associations between words, and choose more relevant and covering key words on the main branches. These findings corroborate the results of previous studies (Farrand et al., 2002) and point to the fact that students can learn to process texts on a deeper level by means of an active practice within ten weeks. Students choose better associated and more relevant and covering key words, which shows that they had internalized the instruction and practice during the mind map training. In this way, the independently constructed mind maps reflect the growth in their text processing skills. With regard to the content coverage of the text information in the mind map and the association between key words, no significant evolution was found between the intermediate test and the posttest. Possibly, students need more time to practice these text processing skills. Acquiring these skills is time consumable and has to be persistently encouraged and followed up (Goodnough & Woods, 2002; Eppler, 2006) As a result, it can be expected that a consequent, systematic, and stimulating supervision of mind map skills will be necessary to avoid the fading out of the positive outcomes of the intervention. Furthermore, an important question that can be addressed in further research is if and how students, who received the training, apply the mind mapping technique to enhance their learning without explicit instructional direction, prompting or supervision.

Although the main conclusion points to a positive effect of mind mapping in stimulating text schematizing and processing, some limitations and suggestions for future research have to be noted.

First, the research data were collected quantitatively and no information was gathered about the experiences and motivational beliefs of students and teachers although those could have an effect on the use of mind maps (Budd, 2004; Treviño, 2005). Second, a larger number of participants is clearly necessary to determine the effects more robustly. This implies an intervention on a larger scale over a longer period of time to map the effects more longitudinally, which is also recommended by D' Antoni et al. (2010). Finally, though it was not in the scope of this research to make a comparison between the text processing and schematizing skills of children who do and do not mind map, the inclusion of comparable conditions would be particularly interesting. It must be noted that in this study, children make a remarkable progress not only in mind map skills but also in processing a text in a structured way by means of mind mapping. This shows evidence for the effectiveness of the developed mind map intervention. By including a comparison or control condition without the mind map intervention, in a more experimental design, future research could reveal whether children in the mind map intervention process, schematize, recall and understand subject matter better and more by using mind mapping than children who do not participate in the intervention. As clarified earlier, the main purpose of this study was examining the mind maps skills of middle grades students, i.e., are they already capable from this age on to make a mind map of an informative text, with regard to the specific characteristics of the map and reflecting the text content in a meaningful way. Finding an answer to this question is a prerequisite for further studies on mind mapping in middle grades. The findings of this study confirm that middle grades students are indeed capable of making mind maps from informative texts in a meaningful way. By including additional text recall and text comprehension measures (e.g., from the sampled test topics), future research should extend beyond the making of mind maps to revealing if and how working with mind maps stimulates the conceptual understanding and ability to recall the information they mapped.

Findings from the present research can be situated within and related to intervention studies in the wider field of studies on self-regulated learning and learning strategy research. Since there is only limited research specifically investigating the role of mind mapping in schematizing informational texts and processing and learning those texts by middle grades students, three concrete suggestions for future research next to those mentioned above could be recommended.

First, it would be interesting to compare whether working with student-generated mind maps is more effective than working with author-provided mind maps in processing and learning informative texts (Lee & Nelson, 2005; Stull & Mayer, 2007). Second, also general learning factors other than the intervention (e.g., learner characteristics, specific learning (dis)abilities) should be taken into account when investigating the impact of a mind map intervention, since we can assume that they play a major role in the effect mind maps can bring about (Vekiri, 2002). Third, a complementary qualitative study would be an added value for interpreting the findings resulting from this study and inspiring future research (Fox, 2009; Scott, 2008). Using a thinking aloud procedure while constructing mind maps from an informative text with a writing pen would be very interesting in this respect. In this way, everything the students say and gradually write down is captured and can be analyzed in depth. This can shed a light on the interplay between children's ongoing text processing, mind mapping and learning from text.

Conclusion

As to the relevance for educational practice, the findings of the present study demonstrate that middle grades students are able to learn to process informative texts by means of an explicit mind map training intervention within a consequent, systematic, and stimulating environment. In this way, a more clear view is presented on how mind maps can be used in stimulating the cognitive component of SRL in classroom practices, a combination which has been rarely studied so far. As to the relevance for research, the study works on the existing gap in the current literature regarding effective approaches for supporting middle grades students to process and learn textual information in a structured way. In this respect, the study enters upon an undeveloped and unexplored research domain for this age group and might inspire other educational researchers to investigate the use of mind maps in middle grades more thoroughly.

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Appendix
Mind Map Scoring Rubric (MMSR)

Name student: Mind map- identification number: Rater:

Shape and organization	1	2	3	4	Total
The main branches are thicker than the sub-branches	Not respected	Generally not respected	Mainly respected	Respected	
On the main branches capitals are used, on the sub-branches small letters are used	Not respected: Use of capitals and small letters is mixed up	Generally not respected: Main branches mainly in small letters, sub-branches mainly in capitals	Mainly respected	Respected	
Use of different colors for every branch	No use of color	Use of different colors within a branch	Mainly correct color use or mind map temporally made in pencil to color afterwards	Every main branch and associated sub-branches are drawn in the same color	
Use of symbols, images and abbreviations	No use	Irrelevant or unclear use	Correct and creative use, Not always relevant	Correct, creative, and relevant use	
Use of arrows, connectors	No use	Incorrect use	Mainly correct and relevant use	Correct and relevant use	
Readability and clearness	MM is not readable without turning the page	MM is only partly readable without turning the page	The content of the MM is mainly readable without turning the page	The MM is readable without turning the page	
Position of key words	None of the key words are placed on the branches	On occasion, key words are placed on the branches	Key words are mainly positioned on the branches	All key words are positioned on the branches	
Mind map structure	Radial structure is not respected	Radial structure is generally not respected	Radial structure is mainly respected	Radial structure is respected	

Content	1	2	3	4	Total
Choice of key words on sub-branches	Sentences are completely copied / long branches	Sentences are mainly copied, too many key words on a branch or irrelevant key words	Key words are mainly relevant and are most of the time nouns and verbs	Key words are relevant, exist of nouns and verbs, good length of the branches	
Content coverage (see expert maps on the next page)	No or little content coverage	Average content coverage	Good content coverage	Almost complete content coverage	
Associations	Words in a branch do not match	Words in a branch do not really match and/or are wrongly associated	Words in a branches match and are mainly well associated	Words in a branch match and are correctly associated	
Choice of key words on main branches	Key words are not relevant or not general enough	Key words are mainly not relevant or not general enough	Key words are mainly relevant and general enough	Key words are relevant and general enough	

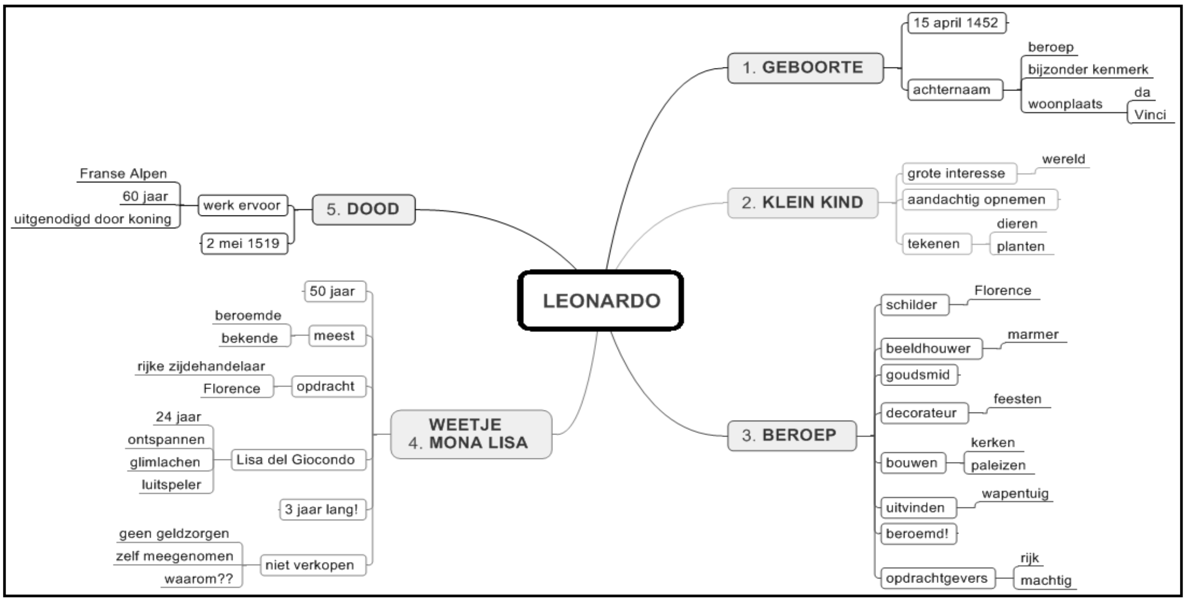
Relevant use of clusters? Pretest: yes ○ no ○ Intermediate test yes ○ no ○ Posttest: yes ○ no ○
Number of relevant clusters? Pretest: _________ Intermediate test: _________ Posttest: _________

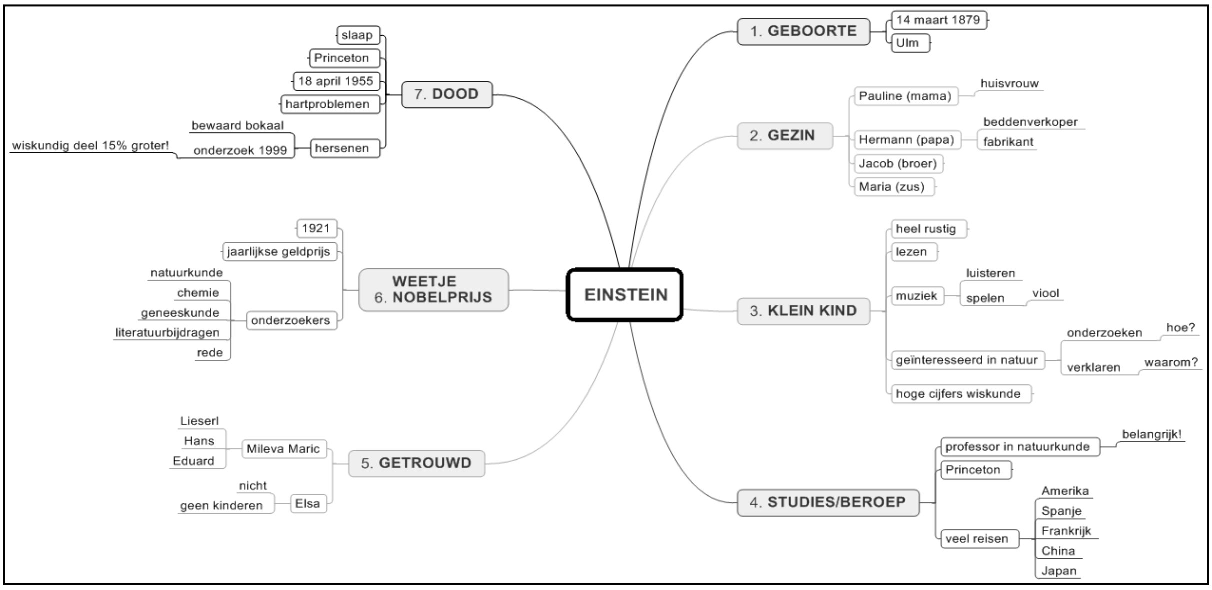
Number of main branches - relevant main branches:____-____ Overall score:____/ 10

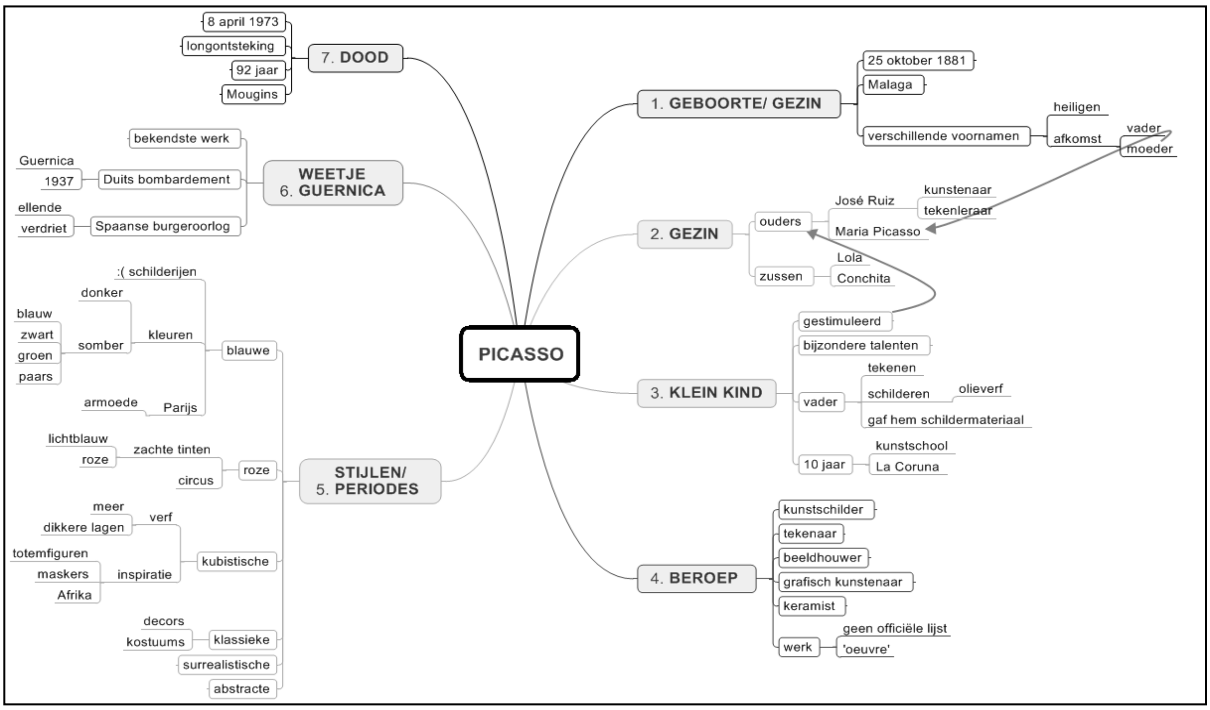
Number of main branches - relevant main branches:____-____ Overall score:____/ 10

Number of main branches - relevant main branches:____-____ Overall score ____/ 10

Content coverage - Expert maps (not colored)







6

Stimulating graphical summarization in late elementary education: The relationship between two instructional mind map approaches and student characteristics

This chapter is based on:

Merchie, E., & Van Keer, H. (2014). Stimulating graphical summarization in late elementary education: The relationship between two instructional mind map approaches and student characteristics. Manuscript accepted for publication in *The Elementary School Journal*.

Chapter 6
Stimulating graphical summarization in late elementary education: The relationship between two instructional mind map approaches and student characteristics

Abstract

This study examined the effectiveness of two instructional mind mapping approaches to stimulate fifth and sixth graders' graphical summarization skills. Thirty-five fifth- and sixth-grade teachers and 644 students from 17 different elementary schools participated. A randomized quasi-experimental repeated measures design was set up with two experimental conditions and one control condition. Students in the experimental conditions followed a 10-week teacher-delivered instructional treatment working with either researcher-provided or student-generated mind maps. Multilevel piecewise growth analysis was used to examine differences between classes and between students within classes, as well as the growth in students' graphical summarization skills and its relationship with class-level (i.e., instructional approach) and student-level (i.e., gender, grade, home language, and achievement level) characteristics. Results show the greatest overall gains for students in the student-generated mind map condition as to the quality of their informative text traces and graphical design. However, no significant differences between the experimental conditions were found as to the quality of the graphical content. Only for gender and grade were significant interaction effects with the instructional approach found.

Introduction

Graphical summarization

Summarization strategies, helping students to process large amounts of textual information into a more condensed form, become more and more important from the age of 11, when informative texts are increasingly used to reach instructional objectives and the expectations for independent text processing increase substantially (Broer, Aarnoutse, Kieviet, & Van Leeuwe, 2002; Schellings & Broekkamp, 2011). These strategies are of high relevance, as writing a summary prompts the use of essential learning strategies, such as elaboration and organization, which have proved to be related to higher levels of cognitive processing and better learning (e.g., Friend, 2001; Leopold, Sumfleth, & Leutner, 2013; Weinstein, Jung, & Acee, 2011; Westby, Culatta, Lawrence, & Hall-Kenyon, 2010). Consequently, it is important to develop and stimulate summarization skills in late elementary education, as they are needed across the curriculum to assist students in their text-based learning.

This study focusses on graphical summarization as a particular summarization strategy. A graphical summary can be defined as the transformation of linear multi-paragraph text into a visually coherent and hierarchically organized spatial structure. In this respect, a graphical summary can be regarded as an extensive and detailed elaborated form of graphic organizer (Stull & Mayer, 2007), wherein usually only a text's main ideas or general structure are outlined. The definition of a graphical summary entails two important elements. First, with regard to the graphical design, the graphical summary incorporates specific characteristics. More particularly, a graphical summary is designed according to gestalt principles such as 'proximity' (grouping of related elements by means of spatial placement) and 'equality' (visual nearness of information by using colors and shapes). These gestalt cues provide an underlying structure to the information. Following these gestalt construction principles results in a higher-quality graphical summary, which in turn promotes faster knowledge identification, processing, and retention (Nesbit & Adesope, 2006; O'Donnell, Dansereau, & Hall, 2002; Wallace, West, Ware, & Dansereau, 1998). Next to the above-mentioned gestalt principles, the connection of drawings to text is another important element integrated into the graphical summary design. By adding a complementary representation to certain keywords, students engage in mental imagery processes that are found to be related to better learning and understanding (Anderson & Hidde, 1971; Leopold et al., 2013).

Second, with regard to the content of the graphical summary, the informative text is summarized succinctly by hierarchically associating super- and subordinate keywords or key sentences to blanket terms that represent main ideas in the text. In this way, the conceptual organization of a text is reflected and the text meaning is extracted thoroughly and precisely (Nesbit & Adesope, 2006; Stull & Mayer, 2007). To indicate text relationships, arrows or connectors can be added. Various studies underpin this manner of hierarchically associating keywords when learning from texts. Hilbert and Renkl (2008), for example, describe in this respect four important functions, i.e., the elaboration function (i.e., determining what is important and relating this to prior knowledge), the reduction function (i.e., concentrating on the macrostructure of the text and deciding on the importance of concepts), the coherence function (i.e., building a coherent knowledge structure), and the metacognitive function (i.e., becoming aware of knowledge and comprehension gaps). Also, other studies have shown that summarizing text content in this way helps students to identify relationships in the text and to analyze, structure, and organize knowledge, in turn promoting deep text processing and learning (Larkin & Simon, 1987; Nesbit & Adesope, 2006; Slotte & Lonka, 1999). In addition, several theories underpin the use of graphical representations of text information. The Dual Coding Theory (Paivio, 1991) and the Cognitive Load Theory (Sweller & Chandler, 1994) point in this respect to advantages in the decrease of cognitive load and the recall of text information due to the simplification of the complex relationships and ideas in the text.

Although the strategy of graphical summarization is promising in nurturing students' general capacity to analyze, structure, and organize knowledge, many students lack knowledge on how to strategically construct summaries (Mateos, Martin, Villalon, & Luna, 2008; Westby et al., 2010). As a result, they tend to use less effective strategies, such as writing everything down linearly or copying the text word for word without synthesizing or relating text information (Westby et al., 2010). Furthermore, little is known about the graphical summarization skills in late elementary education and whether strategy instruction can enhance pre-adolescents' graphical summarization skills.

Graphical summarization strategy instruction

Previous research has already pointed out that a well-planned instructional technique integrated in a longer-term intervention is needed in order to enhance students' learning strategies, such as graphical summarization (e.g., Broer et al., 2002; Dignath, Buettner, & Langfeldt, 2008; Kistner et al., 2010). Unfortunately, however, almost no empirical research evidence exists on effective strategy instructions initiating late elementary students in graphical summarization. Consequently, a deliberately well-founded graphical summarization strategy instruction is needed to stimulate and develop graphical summarization skills. A first important step in this development is identifying crucial strategic activities, guiding students in text selection, organization, and transformation throughout three sequential phases (Alamargot, Plane, Lambert, & Chesnet, 2010; Berninger, Fuller, & Whitaker, 1996; Hilbert & Renkl, 2008; Schlag & Ploetzner, 2011) (Table 1). More particularly, in the pre-writing or planning phase, students focus on text selection and organization by engaging in the strategic activities of text scanning, reading, and clarifying incomprehension. Hereafter, students prepare their graphical summary construction by applying text marking strategies (Frazier, 1993), e.g., underlining or highlighting text information in different colors to visually indicate the text's main and sub ideas. In a second phase, the linear text is transformed into a two-dimensional graphical summary according to specific design elements (e.g., incorporating gestalt principles and images). Here, students engage in various strategic activities such as reducing larger text parts by erasing redundant or trivial information, defining, selecting, translating and relating main, superordinate, and subordinate text ideas, and generalizing and restructuring text into a coherent structure (Brown & Day, 1983; Chang, Sung, & Chen, 2002; Hidi & Anderson, 1986; Westby et al., 2010). In the post-writing or revision phase, students evaluate their graphical summarization process and their constructed product and revise them where necessary. The graphical summarization strategy is constituted when all these strategic activities are coordinated in a goal-oriented way (Schlag & Ploetzner, 2011).

Several types of graphic organizers (e.g., knowledge maps, concept maps) can lend themselves to being incorporated into a graphical summarization strategy instruction. This study specifically opted to incorporate mind maps as a way to graphically summarize text information. Mind maps can be described as higher-level graphic organizers transforming linear text into a graphical representation (Buzan, 1974, 2005). Two important reasons were decisive for including mind maps in the present strategy instruction.

Table 1
Conceptualization of a graphical summarization strategy

Phases	Essential cognitive processes	Sequentially ordered strategic activities
Pre-writing or planning phase	Text selection and organization	(1) Scan the text to get an overview Read the text, and clarify incomprehension (2) Apply text marking strategies: Highlight or structure important text information by means of different colors
Construction phase	Text transformation	(3) Construct your GS, taking into account the graphical design- and content-specific elements
Post-writing or reviewing phase		(4) Review and revise text and GS

Note. GS=graphical summary.

First, a mind map comprises the two essential above-mentioned elements of a graphical summary. In terms of the design, the specific principles (e.g., gestalt principles, use of color, dimension, shape, mental imagery) can be included in a mind map. Related text information is grouped into one 'branch' (i.e., proximity) and presented in the same color (i.e., equality). Furthermore, dimension and different shapes can be added (e.g., writing in capitals on thick branches) to visually indicate more and less important information (i.e., equality). Regarding the graphical content, a mind map allows the text information to be transformed hierarchically. The central text theme is placed in the middle of the page, from which several related main text ideas radiate out. Associated with these main branches, other smaller sub-branches represent sub- and superordinate text ideas. Also, different text relationships (e.g., contrasts, comparisons) can be visualized by adding numbers, arrows, or connectors (Buzan, 2005). Mind maps differ in this respect significantly from the more familiar concept maps (Novak, 2002), which are usually top-down orientated and rely less on specific design principles (e.g., no explicit use of colors, gestalt principles). Second, applying mind maps or similar structures in a graphical summarization strategy instruction in late elementary education has only been explored scientifically to a very limited extent (Broer et al., 2002; Goodnough & Woods, 2002; Merchie & Van Keer, 2013). Although previous research found a significant positive improvement in fifth and sixth graders' ability to graphically represent text information after a researcher-delivered instruction (Merchie & Van Keer, 2013), this has not been explored in authentic learning situations with a teacher-delivered instruction. Most published mind map studies have been executed in secondary or higher education and have focused on mathematics (Brinkmann, 2003), science (Abi-El-Mona & Adb-El-Khalick, 2010), or economics (Budd, 2004). Unfortunately, some studies have not taken into account the essential mind map characteristics (i.e., not using color, dimension, or a clear radial structure), which can cause biased views on the effectiveness of mind maps (e.g., Brinkmann, 2003; Willis & Miertschin, 2006; Zipp, Maher, & D'Antoni, 2009). As a result, there is a great contrast between the frequent use of mind maps in educational practice and the scarcity in scientific underpinnings of this educational practice, particularly in late elementary education. Nesbit and Adesope (2006) plea in this respect for pedagogical models for using maps in whole-class settings. In the present study, the aim is to answer this call and extend previous work by applying a quasi-experimental control group design and by exploring the instructional use of mind maps in graphical summarization strategy instruction.

The role of instruction and student characteristics

Various influencing factors might play a role in the effectiveness of the use of mind maps in graphical summarization strategy instruction. This study explicitly takes into account the following class- and student-level variables: instructional approach, and students' gender, grade, general achievement level, and home language.

A first potentially influencing factor is the applied instructional approach. In this respect, the more indirect 'learning by viewing' approach might be differentiated from the direct 'learning by doing' approach, both associated with some advantages and disadvantages (Kirschner, Sweller, & Clark, 2006; Lee & Nelson, 2005; Stull & Mayer, 2007). In the first approach, learners are provided with researcher-provided maps. These worked examples, already incorporating specific design elements, guide students' attention towards relevant text information, and show how redundant information is deleted and how keywords are hierarchically associated. This should facilitate learning as scaffolds are provided for students' cognitive processing and learners do not have to actively and mentally reconstruct the information themselves. However, autonomous learning would be less promoted in this way. In the 'learning by doing' approach, students are required to select, organize, and associate text information themselves in a coherent structure. This might then again evoke too much cognitive load as extra time and effort have to be invested in cognitive processing (Chang et al., 2002; Leopold et al., 2013; Stull & Mayer, 2007). To our knowledge, no studies have investigated the influence of working with either researcher-provided or student-generated maps in a graphical summarization strategy instruction on (the development of) students' graphical summarization skills.

Second, various student-level characteristics might also be of influence. Students' grade might be a potential influencing factor. Especially in sixth grade, when students are approaching the transition to secondary education, extra attention is paid to the cross-curricular standards stressing the importance of self-regulated learning. In this respect, it might be possible that sixth graders are already more acquainted with certain text-learning or summarization strategies and are therefore more receptive to the use of more complex strategies (Alexander, 1998). Further, research on the influence of gender and organizational strategy use (such as graphical summarization) is rather limited and inconclusive (Rozendaal, Minnaert, & Boekaerts, 2003; Slotte, Lonka, & Lindblom-Ylänne, 2001). Therefore, we aim to take this relationship explicitly into account in the present study. Next, the effectiveness of strategy instruction might differ among students with different ability or achievement levels (Hattie, Biggs, & Purdie, 1996). High achievers are found to be more effective and flexible in their strategy use (Fox, 2009; Vauras, Kinnunen, & Kuusela, 1994). In contrast, Hattie et al. (1996) reported that low- and high-ability students might benefit the least from strategy instruction. Therefore, this study also takes into account the influence of students' general achievement level (i.e., low, average, or high). A final possible influencing student characteristic is students' home language, since students with lower proficiency in the instructional language might experience more difficulty with graphical summarization (Nesbit & Adesope, 2006). Next to these possible influencing factors, it is also important to consider whether different groups of learners benefit more from working with either researcher-provided or student-generated maps. In this respect, some learners with lower prior knowledge of the strategic activities included in the graphical summarization strategy instruction (e.g., fifth graders) or with lower (verbal) abilities (e.g., low achievers or nonnative speakers) might benefit more from working with worked examples (O'Donnell et al., 2002; Vekiri, 2002). In this study, these possible aptitude-by-treatment interactions (Cronbach & Snow, 1969; Jonassen & Grabowski, 1993) are explicitly taken into account.

In sum, the present study focusses on the following research questions:

1. Can the developed graphical summarization strategy instruction be used effectively in late elementary grades to stimulate graphical summarization skills?
2. Does the instructional approach (i.e., working with researcher-provided or student-generated maps) influence students' graphical summarization skills?
3. To what extent are students' characteristics related to students' graphical summarization skills and are there any interaction effects between the instructional approach and students' characteristics?

Method

Design

A quasi-experimental repeated measures design (i.e., pretest, posttest, retention test) was applied. Schools were randomly assigned to either (a) a researcher-provided mind map condition, (b) a student-generated mind map condition, or (c) a control condition. Fifth- and sixth-grade teachers from the same school were assigned to the same condition, to avoid design contamination effects. Teachers in the experimental conditions embedded one specific teacher-delivered instructional mind map approach into a graphical summarization strategy instruction once a week over a 10-week period in their social study and science lessons during regular classroom hours. Classes assigned to the control condition followed their usual teaching repertoire, and were provided with the instructional material of the experimental conditions only during the subsequent school year. In this respect, although graphic organizers are occasionally referred to in teachers' regular teaching repertoire, control condition students did not receive any systematic and explicit graphical summarization strategy instruction. No attrition occurred over time across the different conditions as neither schools nor individual teachers withdrew their study participation.

Procedure

The conducted research consisted of five phases: (1) pretest administration (September 2011); (2) a 1.5-hour after-school training for teachers in the experimental conditions (September 2011); (3) 10-week intervention period; (4) posttest administration (December 2011); and (5) retention test administration (March 2012). Passive informed consent was obtained from all parents of the fifth- and sixth-grade students as they were provided with the opportunity to withdraw their child from participation in the study. Figure 1 illustrates the design and procedure of the study.

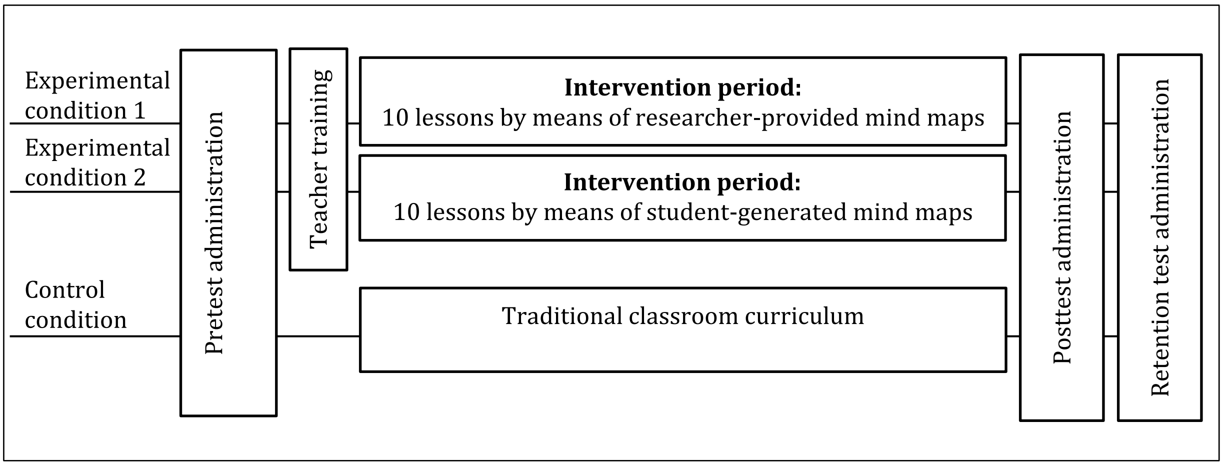


Figure 2. Design of the study.

Participants

Fourteen fifth-grade teachers, fifteen sixth-grade and six multigrade teachers and their 644 students from 17 different elementary schools throughout Flanders (the Flemish-speaking part of Belgium) participated in the study. Multigrade teachers teach multigrade classes comprising students from both fifth and sixth grade, who retain, however, their grade-specific designation and textbooks (Mulryan-Kyne, 2007). Students' average age was 11.44 (*SD*=0.68), with 53.9% boys and 46.1% girls. The average class size was approximately 19 students (*SD*=4.68) per class. The majority of the students had Dutch as their home language (94.5%), which is the instructional language in Flanders. Teachers were on average 34.74 years old (*SD*=9.49) and had on average 13.77 years (*SD*=9.21) of teaching experience. Eight teachers were men (22.9%). Experienced teachers are believed to make accurate judgments on students' general achievement level (Boekaerts, Pintrich, & Zeidner, 2000; Desoete, 2008). Therefore, they were asked to specify for each individual student whether they could be considered in general as a high achiever, an average achiever, or a low achiever, bearing in mind students' text comprehension and study competencies.

Table 2 summarizes students' individual characteristics (gender, home language, grade, and achievement level) in the three research conditions. Chi-square analyses indicated no significant differences in the distribution of home language ($\chi 2$=5.00, *df* =2, *p*=.08), grade ($\chi 2$=7.55, *df* =2, *p*=.02), and general achievement level ($\chi 2$=3.73, *df* =4, *p*=.44). For gender, a significant difference in distribution was found($\chi 2$=7.55, *df* =2, *p*=.02), as the control condition included more boys. As for the characteristics of the teachers in all conditions, chi-square analyses indicated no significant differences in the distribution of gender ($\chi 2$=0.41, *df* =2, *p*=.21) and grade ($\chi 2$=0.69, *df* =4, *p*=.31) across conditions. Furthermore, one-way analysis of variance indicated no significant differences between the three conditions regarding teachers' mean age (F(2,34)=0.13, *p*=.88) and teaching experience (F(2,34)=0.27, *p*=.77).

Table 2
Student characteristics

	Experimental condition 1 RPMM condition		Experimental condition 2 SGMM condition		Control group	
	N	%	*N*	%	*N*	%
Gender						
Male	109	50.9	108	49.3	130	61.3
Female	104	49.1	111	50.7	82	38.7
Total	213	100	219	100	212	100
Home language						
Dutch	191	91.8	209	96.8	200	94.8
Other language	17	8.2	7	3.2	11	5.2
Total	208	100	216	100	211	100
Grade						
Fifth grade	95	44.8	92	42.0	106	50
Sixth grade	118	55.2	127	58.0	106	50
Total	213	100	219	100	212	100
Achievement level						
High achiever	90	42.2	96	44.4	105	49.5
Average achiever	76	35.7	81	37.5	73	34.4
Low achiever	47	22.1	39	18.1	34	16.1
Total	213	100	216	100	212	100

Note. RPMM=researcher provided mind map, SGMM=student-generated mind map.

Intervention

General aim and structure

A previously tested researcher-directed mind map training (Merchie & Van Keer, 2013) was used as the basis for the development of two lesson programs each focussing on a different instructional mind map approach. Both programs include 10 lessons of 50 minutes each, spread over 10 consecutive weeks, and share a general structure. In the first lesson, students were introduced to essential graphical mind map design elements. More particularly, they were pointed towards seven important design principles stressed throughout the whole lesson series. The first three principles were related to the gestalt principles 'proximity' and 'equality' encouraging the application of different dimensions, shapes and colors, i.e., main branches, directly associated with the central topic, are thicker than sub-branches (design principle 1), capital letters are used on the main branches, small letters on the sub-branches (design principle 2), and a different color is used for every main branch and its associated sub-branches (design principle 3). Further, mental imagery processes were stimulated by design principle 4, i.e., connecting images to keywords or replacing keywords with images. Finally, three design principles assured the construction of a coherent structure, i.e., the graphical summary must be readable without turning the page (design principle 5), keywords must be placed on the branches (design principle 6), and the radial map structure must be respected (design principle 7). The second to ninth lessons were devoted to the gradual instruction of graphical summarization. This strategy instruction was guided by the strategic activities implemented in the three sequentially ordered phases presented in Table 1. The 10^{th} and final lesson was spent on mind mapping in multiple content areas (e.g., writing, mathematics, French).

Two different instructional approaches

Regardless of the similar structure and included grade-specific informative texts, both strategy programs differ significantly in the way graphical summarization was induced and stimulated. As for the first instructional approach, which was implemented in experimental condition 1, an indirect instructional approach with researcher-provided mind maps was applied (see Appendix A for an overview of an example lesson). After scanning, reading, and structuring the text in the pre-writing phase, students received different types of exercises (e.g., fill in the blank, open questions, searching for answers in the mind map) during the construction phase to complete with the texts and accompanied researcher-provided mind map. In this way, it was ensured that students studied the provided graphical summary in detail and consequently the way in which the text information is transformed (e.g., the choice and association of blanket terms and keywords, the hierarchical transformation of text information, the inclusion of text relationships). Assignment solutions were discussed during the post-writing or evaluation phase. In each of the ten lesson, complete researcher-provided mind maps were used. As for the second instructional approach, which was implemented in experimental condition 2, student-generated mind maps were used for initiating graphical summarization. Students were gradually taught to construct graphical summaries themselves (e.g., incorporating the design principles, choosing relevant blanket terms, hierarchically associating keywords, including arrows) by means of a step-by-step plan reflecting the sequentially ordered strategic activities in graphical summary construction (see Table 1 and Appendix B for an overview of an example lesson). In this respect, students gradually progressed from drawing parts of a graphical summary during lesson one to four (e.g., adding sub-branches, adding a complete main branch) and were explicitly instructed to independently construct complete graphical summaries themselves during lesson five to ten.

Instructional material

Informative texts included in both strategy programs were identical and derived from students' grade-specific social studies and science textbooks. Different multi-paragraph texts were provided for fifth and sixth grade, addressing grade-specific subject matter. As lessons progressed, structural clues and signaling devices in the texts (e.g., subheadings, words printed in italics or boldface) (Lorch, 1989) were gradually omitted. Mind maps, reflecting a graphical summary of the text information, included in the lessons were drawn by hand by a trained researcher, carefully respecting the graphical design principles. Paper-and-pencil- instead of computer-drawn mind maps were purposefully used, as this was most similar to students' paper and pencil assignments. On the basis of prior research (Merchie & Van Keer, 2013), these texts and mind maps were previously evaluated and adjusted as to their length, difficulty, clarity, content, and organization.

Classes in the experimental conditions were provided with all necessary teaching materials to implement the lessons. All students received a learning book wherein all color-print lessons (i.e., the informative texts, mind maps, and worksheets) were included. Teachers were provided with teacher manuals, comprising the 10 detailed lesson plans with lesson objectives and assignment solutions, classroom posters, and a compilation reader with additional background information on mind mapping.

Training

One week before the intervention and after pretest administration, all experimental schools were individually visited, providing fifth- and sixth-grade teachers with a researcher-directed 1.5 hours of after-school training. At the beginning of the training, each teacher was provided with a grade-specific teacher manual, for lesson preparation and consultancy reference when delivering instruction (100 pages), and with a compilation reader with background mind map information (125 pages). The training consisted of the following parts: (1) a detailed description of the rationale of the study, (2) a demonstration and exemplification of the specific mind map design principles and the use of mind mapping as a graphical summarization strategy, and (3) a thorough presentation of the instructional materials, including an overview of the phases, topics, structured activities, and classroom assignments.

Fidelity to treatment

Three methods were applied to ensure treatment fidelity (O'Donnell, 2008; Swanson, Wanzek, Haring, Ciullo, & McCulley, 2013). First, teachers were asked to complete a booklet with 10 structured protocols (one per lesson) throughout the intervention. In the protocols, teachers indicated the date and hour of and total time spent on each lesson. Teachers furthermore evaluated on a five-point scale the degree to which (a) each lesson objective (reflecting critical intervention components and stated in teachers' manuals) was attained, (b) each assigned activity was completed, and (c) instructional materials were clear. Two open questions asked for teachers' additional remarks or suggestions. From these protocols, it was clear that the requested frequency of one lesson per week was realized. The average time spent on lessons ranged from 45 minutes to 70 minutes, without significant differences between conditions (p=.116). Second, teachers were encouraged to implement the lessons and to complete their protocols by three-weekly phone calls and personalized electronic reminders. Additionally, schools had the opportunity to receive an additional school visit when having questions or instructional difficulties. Third, after the intervention, teachers received an additional questionnaire, showing that in both conditions students were motivated and concentrated and teachers experienced no difficulties to implement the lessons. They reported that the instructional program helped them to implement graphical summarization strategy instruction in their regular curriculum. Furthermore, they underlined the attractiveness of the materials and reported that they had largely achieved the main lesson objectives.

Dependent measures

To measure students' graphical summarization skills, a task was administered that encompassed independently graphically summarizing an informative text during a time span of 30 minutes. This finite amount of study time served to elicit the regulation of study activities as efficiently as possible. Students who did not know what a graphical summary was, received a short description: 'A graphical summary is an overview of the ideas in the text, linked together in a certain way.' No further construction guidelines or prompts were given (Hilbert & Renkl, 2008). For the three measurement occasions, three different informative texts were used, containing on average 322 words, respectively about the life of seahorses (pretest), meerkats (posttest), and hummingbirds (retention test). The same texts were used for fifth and sixth grade. All texts were analyzed by an institute for test development (CITO). The three texts were found to be appropriate for this age group and very comparable on indexes indicating their technical reading level (TRL) (TRL_{pre}=AVI-E7, TRL_{post}=AVI+, TRL_{ret} AVI+) and reading comprehension level (RCL) (RCL_{pre}=CLIB 8, RCL_{post}=CLIB 8, RCL_{ret}=CLIB 8)[1]. Texts were subdivided into three text paragraphs accompanied by the following subheadings: general information, body parts, and habitat. Students received a sheet of blank paper to construct their graphical summary. The texts applied during the test were similar to those used in the lesson series (Broer et al., 2002). Students' informative texts and graphical summaries were collected for detailed trace analysis. A trace is a direct observable indicator of students' actions left behind

[1] In Flanders, the AVI-index (i.e., Analyse Van Individualiseringsvormen [*Analysis of Individualization Forms*]) is used to indicate texts' technical reading level. The index contains twelve difficulty levels, starting with 'AVI-start' being the easiest to 'AVI+' being the most difficult. Texts indexed with an AVI E7- and AVI+-level are appropriate for fifth and sixth graders. The CLIB-index (i.e., Cito LeesIndex voor het Basis- en speciaal onderwijs [*Cito ReadingIndex for elementary and special education*]) distinguishes texts into eight reading comprehension and conceptual difficulty levels, ranging from 'CLIB-start' to 'CLIB 8'. Texts with a CLIB 7- and CLIB 8-level are appropriate for fifth and sixth graders.

after task execution (e.g., markings of key words in the text, the use of color, written down key words in the graphical summary).

Students' graphical summarization skills were analyzed in three subsequent steps. First, the quality of the informative text traces was verified, as they provide an indication of students' engagement during the pre-writing phase. Second, the graphical summaries' design and content were investigated. In these two subsequent steps, detailed trace analyses were conducted (Winne, 2010). For this purpose, analytic scoring rubrics were developed (Meier, Rich, & Cady, 2006; Nitko & Brookhart, 2007) as reliable scoring methods are very scarce. The developed scoring rubrics were accompanied by an extensive scoring manual with various illustrating examples. First, informative text traces were scored on a five-point scale for the following four categories: (sub)title markings, figure markings, color use for distinguishing main and sub ideas, and number of used colors (Appendix C). Based on these scores, an overall mean score was calculated, representing the overall quality of the informative text traces (α_{pre}=.72, α_{post}=.80, α_{ret}=.79). The stability of this one-factor model obtained good model fit results in a confirmatory factor analysis (CFA) (YB χ^2=161.157, *df*=6, *p* <.001, CFI=.99, TLI=.99, RMSEA=.02 with a 90% CI [.00, .02], SRMR=.02).

Second, a previously developed scoring rubric (Merchie & Van Keer, 2013) (Appendix D) was applied to analyze different components regarding the graphical design. As for the graphical design, the following subcomponents related to the specific design principles were scored on a five-point scale: branch dimension, letter dimension, color use, inclusion of images, readability, placing keywords, and radial structure. Based on these scores, an overall mean score was calculated, representing the overall quality of the graphical summary design (α_{pre}=.92, α_{post}=.93, α_{ret}=.91). The stability of this one-factor model obtained good model fit results in a CFA (YB χ^2=522.102, *df*=21, *p* <.001, CFI=.97, TLI=.95, RMSEA=.04 with a 90% CI [.03, .06], SRMR=.01).

Third, the previously developed scoring rubric (Merchie & Van Keer, 2013) (Appendix D) was applied to analyze different components regarding the graphical content. The following subcomponents were scored on a five-point scale: inclusion of arrows, choice of keywords, content coverage, associations, choice of blanket term, and deepening (i.e., the degree to which whole main branches are hierarchically elaborated). Based on these scores, an overall mean score was calculated, representing the overall quality of the graphical summary's content (α_{pre}=.94, α_{post}=.94, α_{ret}=.91). Also, the stability of this one-factor model obtained good model fit results in a CFA (YB χ^2=161.157, *df*=6, *p* <.001, CFI=.99, TLI=.99, RMSEA=.02 with a 90% CI [.00, .02], SRMR=.02).

A detailed trace analysis was conducted by a team of three raters, after the three measurement moments. Ratings were completed within a time frame of two subsequent weeks. At the beginning of the first week, raters received a one-day training on applying the analytic scoring rubrics. They were provided with a coding manual (37 pages), wherein the trace methodology procedure was described in detail and the different to-be-scored subcomponents of the analytic scoring rubrics were illustrated with an example. After the training session, raters worked independently on the tests of randomly assigned classes. Study materials from 227 students (35%) (78 researcher-provided mind map condition students, 74 student-generated mind map condition students, and 75 control condition students) were double-coded for the three measurement occasions to check interrater reliability by means of Krippendorff's alpha (Hayes & Krippendorff, 2007). Good to excellent Krippendorff's alpha (α) interrater reliability coefficients of the coded trace categories ranging from .89 to 1 indicated good to excellent interrater reliability. In this respect, an overall score for the three main components (i.e., informative text traces, graphical design, and graphical content) was obtained and detailed analyses on the subcomponents were allowed (Appendix C, D).

Data analysis

To investigate the short-term (posttest) and relatively longer-term (retention test) effects of both graphical summarization strategy instruction programs on students' graphical summarization skills, multilevel piecewise growth analyses were performed in MLwiN 2.25 as the data under investigation have a clear hierarchical three-level structure. More particularly, measurement occasions (i.e., pre-, post-, and retention test) (level 1) are clustered within students (level 2), which are in turn nested within classes (level 3). In this respect, the interdependency between students, as belonging to the same class and sharing common experiences, was explicitly taken into account (Maas & Hox, 2005). Multigrade classes were included as one class in the analyses. In view of the analyses, the time span from pretest to retention test is split into a first piece or phase (P1) covering students' growth from pretest to posttest, and a second piece or phase (P2) covering students' growth from posttest to retention test. These different phases are included in the model as repeated-measures dummy variables with correlated residuals at the student level.

A stepwise analysis procedure was followed. In the first step of the analysis, a three-level conceptual null model was estimated, which served as a baseline to compare with more complex models. This null model predicts the overall pretest score on the dependent variable and the overall growth from pretest to posttest (P1=phase 1) and from posttest to retention test (P2=phase 2) for all students across all classes. In a second step, the experimental conditions were included in the model to investigate the differential pretest scores of the experimental groups contrasted against the control group. In a third step, interaction effects were included between the experimental conditions and P1 and P2 to investigate the differential growth of the experimental groups from pretest to posttest (interaction with P1) and from posttest to retention test (interaction with P2) contrasted against the control group. Based on this model, research questions 1 and 2 were answered. To answer research question 3, individual learner characteristics (i.e., gender, grade, home language, and achievement level) were first included as explanatory variables in the fixed part of the model. Next, main effects as well as interaction effects with P1 and P2 and with the conditions were added.

Results

Effects of graphical summarization instruction: Experimental versus control condition students

In terms of the first research question, it was verified whether experimental condition students grow significantly different in their graphical summarization skills to control condition students.

Table 3 more particularly summarizes the model estimates for the three-level analyses of respectively the total scores of the quality of the informative text traces, graphical design, and graphical content. More information on the model estimates for the detailed three-level analyses of the scored subcomponents can be found in Appendix E. In the columns 'pretest score,' 'phase 1,' and 'phase 2,' information on the fixed part of the models is included. The intercept β_0 (pretest column) represents the mean pretest score for all students in all control condition classes. The parameters β_1 (phase 1 column) and β_2 (phase 2 column) must be added to or subtracted from β_0 to obtain the mean post- and retention test score for all students in all control condition classes. β_1 and β_2 represent the average growth (positive or negative) from pretest to posttest and from posttest to retention test respectively for all students in all control condition classes. The parameters β_3 and β_4 for the researcher-provided and student-generated mind map condition (pretest column) are differential parameters with respect to the control condition and consequently must be added to or subtracted from the control condition pretest score to obtain the mean pretest score for all students in all classes in respectively the researcher-provided and student-generated mind map condition. The parameters β_5 and β_6 (phase 1 column) are differential with respect to β_1 and represent the mean differential growth (positive or negative) or the differential increase or decrease from pre- to posttest for the experimental condition classes with respect to the control condition. β_7 and β_8 (phase 2 column) are differential with respect to β_2 and represent the mean differential growth (positive or negative) from post- to retention test for the experimental condition classes with respect to the control condition. In the last column of the Tables, information on the random part of the model is included. Here, the variances at the three levels are represented, based on the conceptual null models, showing for each separate subscale the total variance partitioned into the between-classes variance (level 3), between-students within-classes variance (level 2), and between-measurements within-students variance (level 1). With regard to the traces in the informative text, students from both experimental conditions show a significantly larger growth than control condition students in phase 1. This is reflected in their overall informative text score (χ^2_{RPMM}=11.315, *df*=1, p <.001; χ^2_{SGMM}=105.425, *df*=1, p <.001). As a result, mean scores at posttest from both experimental conditions differ significantly from control students (χ^2_{RPMM}=6.249, *df*=1, p=.012; χ^2_{SGMM}=40.962, *df*=1, p <.001). Although student-generated mind map condition students show a significant decline in phase 2 (χ^2_{SGMM}=19.871, *df*=1, p <.001) when contrasted with the control students, they still obtain significantly higher scores at retention test (χ^2_{SGMM}=12.104, *df*=1, p <.001). Researcher-provided mind map condition students' growth during phase 2, however, does not differ significantly from that of control students (χ^2_{RPMM}=1.499, *df*=1, *p*=.221). At retention test, no significant differences between researcher-provided mind map condition students and control students occur (χ^2_{RPMM}=2.694, *df*=1, *p*=.101).

As for the graphical summary's design, both experimental condition students show a significantly larger growth during phase 1 when contrasted with the control students (χ^2_{RPMM}=341.179, *df*=1, *p* <.001; χ^2_{SGMM}=619.926, *df*=1, *p* <.001). Experimental students' growth declines significantly during phase 2 (χ^2_{RPMM}=16.990, *df*=1, *p* <.001; χ^2_{SGMM}=27.557, *df*=1, *p* <.001). However, they still obtain significantly higher mean retention test scores than control students ($\chi 2_{RPMM}$=142.776, df=1, *p* <.001; $\chi 2_{SGMM}$=260.507, df=1, *p* <.001).

With regard to the graphical summary's content scores, a similar pattern occurs. A significantly larger growth is shown during phase 1 in the experimental conditions' scores when contrasted with the control condition (χ^2_{RPMM}=295.852, *df*=1, *p* <.001; χ^2_{SGMM}=304.771, *df*=1, *p* <.001). Although their progress significantly declines during phase 2 (χ^2_{RPMM}=18.820, *df*=1, *p* <.001; χ^2_{SGMM}=23.085, *df*=1, *p* <.001), they still outperform control students at retention test (χ^2_{RPMM}=144.358, *df*=1, *p* <.001; χ^2_{SGMM}=146.852, *df*=1, *p* <.001). Figure 2 shows an illustrative example of the differences between a researcher-provided mind map (RPMM) condition, a student-generated mind map (SGMM) condition, and a control condition student.

Effects of instructional approach: Working with researcher-provided vs. student-generated maps

In order to answer the second research question, further analyses were conducted to explore the differential impact of the two experimental instructional approaches on students' graphical summarization skills. Three main findings draw our attention. First, student-generated mind map condition students outperform researcher-provided mind map students both at posttest (χ^2=33.002, *df*=1, *p* <.001) and retention test (χ^2=10.326, *df*=1, *p* <.001) in their text selection and organization. A similar pattern occurs with the graphical summary's design, as student-generated mind map condition students obtain significantly higher scores at posttest (χ^2=33.423, *df*=1, *p* <.001) and retention test (χ^2=25.227, *df*=1, *p* <.001). Second, it is notable that researcher-provided mind map condition students grow significantly more than student-generated mind map condition students during phase 1 in terms of including images in their graphical summary (χ^2=7.678, *df*=1, *p*=.006). Figure 3 illustrates, in this respect, the effective image incorporation in a few main branches of a researcher-provided mind map condition student's map. Third, no significant differences occur with regard to the overall graphical summary's content score on either posttest (χ^2=1.144, *df*=1, *p*=.284) or retention test (χ^2=0.590, *df*=1, *p*=.442). However, when looking into detail, student-generated mind map condition students obtain significantly higher scores on both post- (χ^2=5.237, *df*=1, *p*=.022) and retention test (χ^2=5.114, *df*=1, *p*=.024) regarding the choice of an adequate blanket term to further elaborate on. Figure 4 compares the program effects by summarizing the significant differences across conditions for students' total scores on the quality of their informative text traces, graphical design, and graphical content.

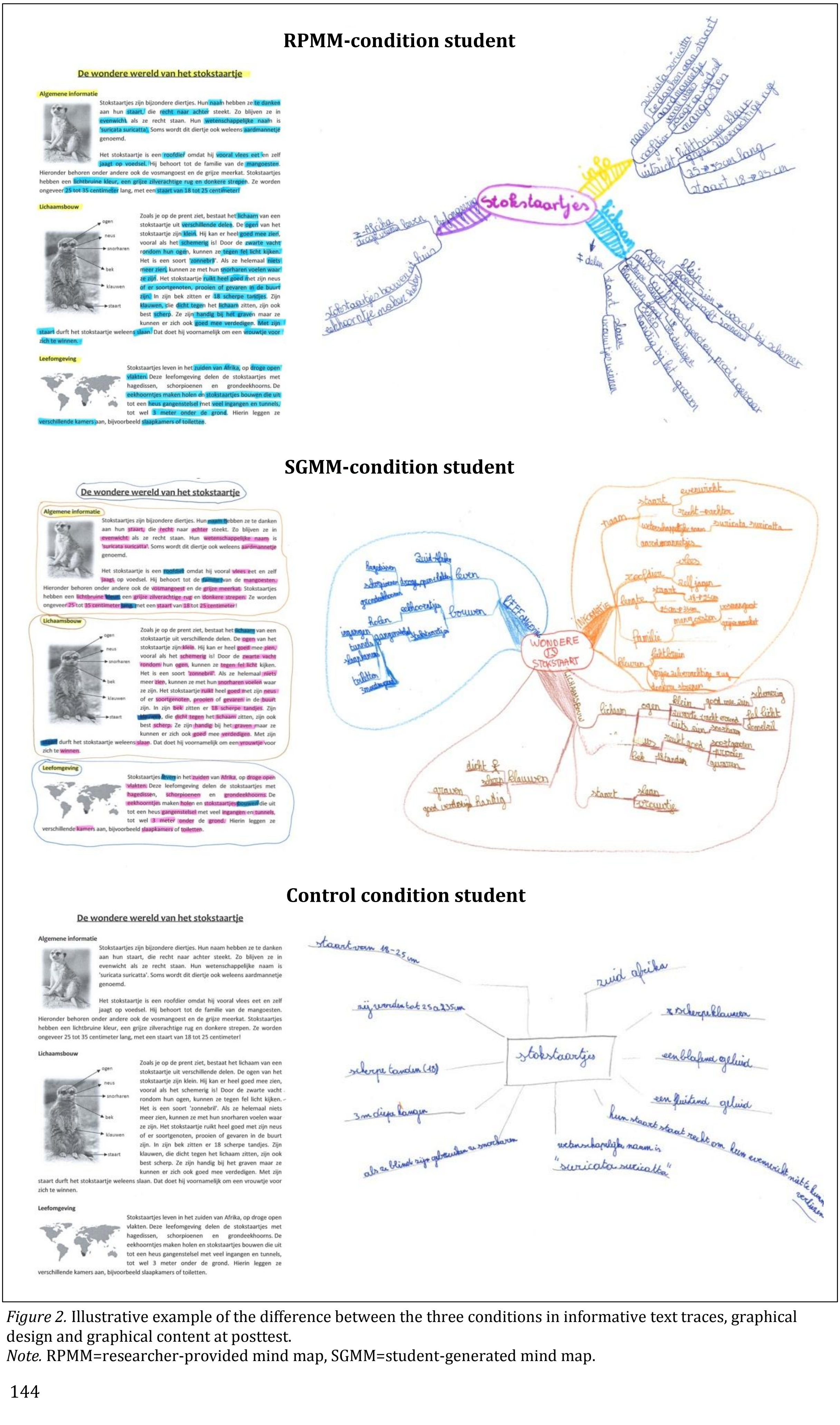


Figure 2. Illustrative example of the difference between the three conditions in informative text traces, graphical design and graphical content at posttest.
Note. RPMM=researcher-provided mind map, SGMM=student-generated mind map.

Table 3

Summary of the model estimates[a] for the three-level analysis of the total scores of the quality of the informative text traces, graphical design, and graphical content for the three conditions[b]

	Fixed part									Random part		
	Pretest score			**Phase 1 (Growth from pre- to posttest)**			**Phase 2 (Growth from posttest to retention test)**			**Variances at the three levels[c] σ^2(*SD*)**		**Proportion of the variance at the three levels**
	RPMM Condition β_3	**SGMM Condition β_4**	**Control condition Intercept β_0**	**RPMM Condition β_5**	**SGMM Condition β_6**	**Reference category: Control condition β_1**	**RPMM Condition β_7**	**SGMM Condition β_8**	**Reference category: Control condition β_2**			
Total score informative text	0.015 (0.109)	-0.039 (0.116)	0.201 (0.080)*	0.259 (0.077)*	0.781 (0.076)*	-0.086 (0.054)	-0.094 (0.077)	-0.339 (0.076)*	0.057 (0.054)	3	0.138(0.038)*	13.87%*
										2	0.126(0.024)*	12.66%*
										1	0.731(0.029)*	73.47%*
Total score graphical design	0.189 (0.127)	0.371 (0.134)*	0.304 (0.093)*	1.710 (0.093)*	2.278 (0.091)*	0.243 (0.065)	-0.382 (0.093)*	-0.481 (0.092)*	0.276 (0.065)*	3	0.441(0.018)*	76.56%*
										2	0.066(0.014)	11.46%
										1	0.069(0.019)*	11.98%*
Total score graphical content	0.269 (0.114)*	0.390 (0.121)*	0.262 (0.084)*	1.475 (0.086)*	1.480 (0.085)*	0.196 (0.060)*	-0.372 (0.068)*	-0.407 (0.085)*	0.297 (0.061)*	3	0.055(0.016)*	11.32%*
										2	0.052(0.012)*	10.70%*
										1	0.379(0.015)*	77.98%*

Note. [a] Significant parameters are indicated with an asterisk (*), standard error estimates are placed between brackets; [b] RPMM condition= researcher-provided mind map condition, SGMM condition= student-generated mind map condition; [c] 3= class-level variance, 2 = student-level variance, 1 = measurement occasion-level variance in the fully unconditional three-level null models.

Note. Model equation

$y \sim \mathrm{N}(X\mathrm{B},\Omega)$

$y_{\mathrm{ijk}} = \beta_{0\,\mathrm{ijk}}\,\mathrm{CONS} + \beta_1.\mathrm{p1}_{\mathrm{IJK}} + \beta_2.\mathrm{p2}_{\mathrm{ijk}} + \beta_3\,\mathrm{RPMM}_{\mathrm{k}} + \beta_4\,\mathrm{SGMM}_{\mathrm{k}} + \beta_5\,\mathrm{RPMM.p1}_{\mathrm{ijk}} + \beta_6\,\mathrm{SGMM.p1}_{\mathrm{ijk}} + \beta_7\,\mathrm{RPMM.p2}_{\mathrm{ijk}} + \beta_8\,\mathrm{SGMM.p2}_{\mathrm{ijk}}$

$\beta_{0\,\mathrm{ijk}} = \beta_0 + \mathrm{v}_{\mathrm{ok}} + \mathrm{e}_{\mathrm{0jk}} + \mathrm{e}_{\mathrm{0\,ijk}}$

$[\,v_{\mathrm{ok}}\,] \sim \mathrm{N}(0,\Omega_v) : \Omega_v = [\sigma^2_{\mathrm{v}\,0}]$

$[\,u_{\mathrm{ojk}}\,] \sim \mathrm{N}(0,\Omega_u) : \Omega_u = [\sigma^2_{\mathrm{u}\,0}]$

$[\,e_{\mathrm{oijk}}\,] \sim \mathrm{N}(0,\Omega_e) : \Omega_e = [\sigma^2_{\mathrm{e}\,0}]$

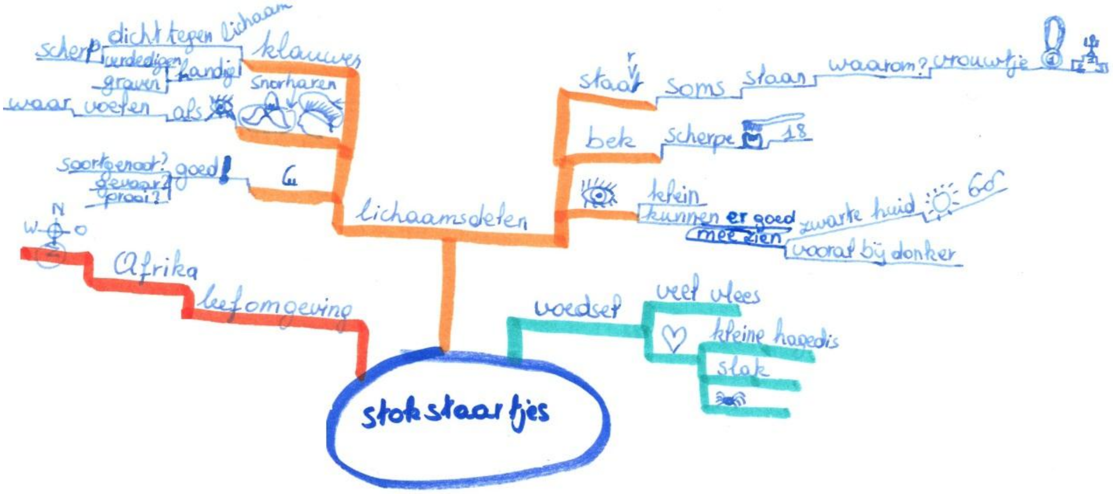


Figure 3. Example of the effective image incorporation into several main branches of a researcher-provided mind map condition student's map.

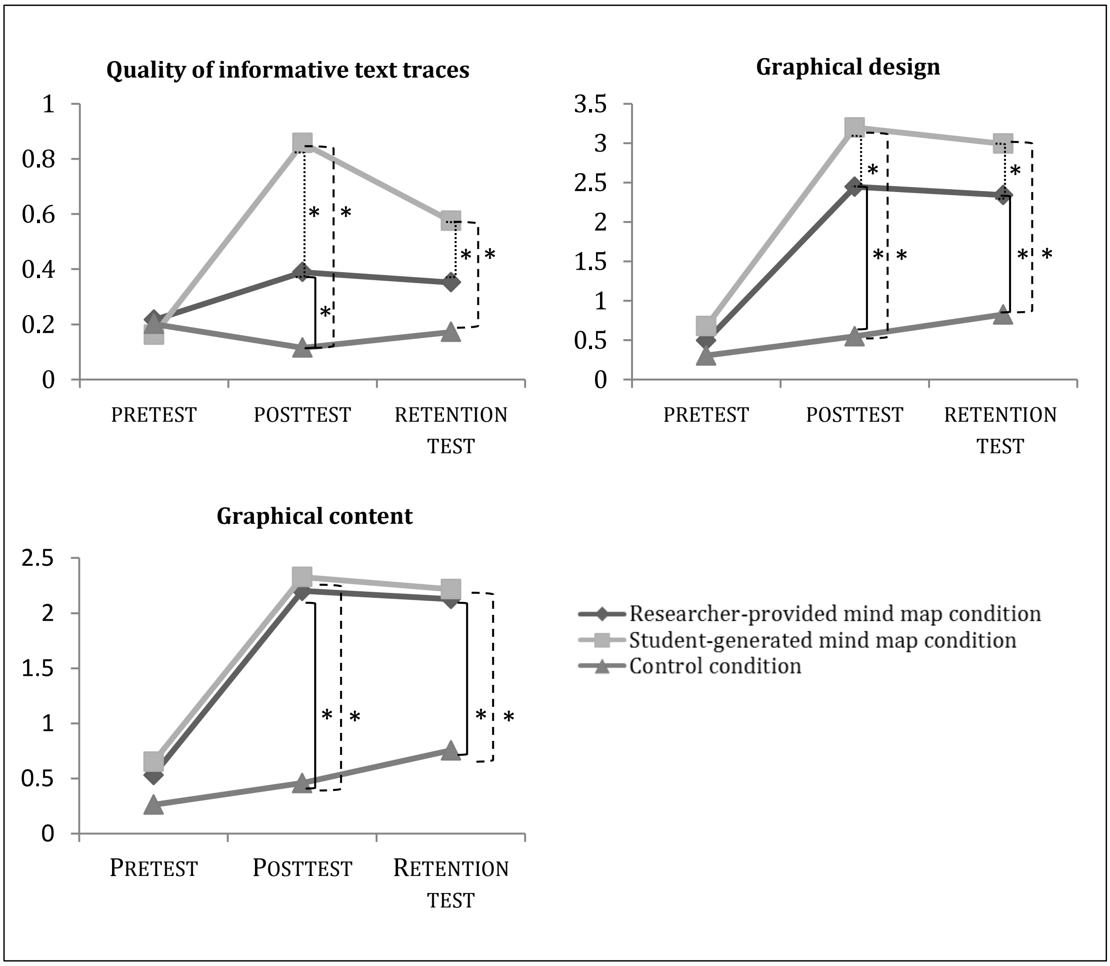


Figure 4. Students' growth regarding quality of informative text traces, graphical design, and graphical content for the three conditions. Significant differences are indicated with an asterisk (*).

Graphical summarization skills: Relationship with students' characteristics and interaction effects between instructional approach and students' characteristics

In terms of the third research question, potential interaction effects were explored between the different instructional approaches and specific individual learner characteristics. Within the researcher-provided mind map condition, girls show a significantly larger growth than boys in their overall informative text score during phase 1 (χ^2=6.801, *df*=1, *p*=.009) (Table 6). However, with regard to the graphical design and content, no significant differences during phase 1 ($\chi^2_{graphical\ design}$=1.756, *df*=1, *p*=.185; $\chi^2_{graphical\ content}$=0.109, *df*=1, *p*=.741) and 2 ($\chi^2_{graphical\ design}$=1.631, *df*=1, *p*=.201; $\chi^2_{graphical\ content}$=0.014, *df*=1, *p*=.906) were found between girls and boys in the researcher-provided mind map condition. With regard to grade, home language, and general achievement level, no significant differences occur for overall informative text score, graphical design, or graphical content within the researcher-provided mind map condition.

Within the student-generated mind map condition, significant differences occur between girls and boys with regard to the graphical design, where girls significantly progress more during phase 1 than boys (χ^2=4.386, *df*=1, *p*=.036). Further, with regard to students' grade, sixth graders show a significantly larger growth during phase 2 with regard to their overall informative text score (χ^2=4.348, *df*=1, *p*=.037) and their graphical content score during phase 1 (χ^2=7.949, *df*=1, *p*=.005) (Table 4). Further, however, no significance differences were found regarding home language or general achievement level within the student-generated mind map condition.

Finally, possible aptitude-by-treatment interactions (i.e., interaction effects among instructional approaches and student characteristics) were also studied. More specifically, it was hypothesized that certain groups might have benefited more from working with worked-out examples, i.e., (1) fifth graders, possibly not that much acquainted yet with more complex strategies such as summarizing, (2) low achievers, believed to be not so effective in their strategy use, or (3) nonnative speakers, who might have lower proficiency in the instructional language (Alexander, 1998; Hattie et al., 1996; Nesbit & Adesope, 2006; Vekiri, 2002). Also, the relationship with gender and instructional approach was investigated. The analyses, however, revealed no significant interaction effects.

Table 4

Summary of the model estimates[a] for the three-level analysis of the interaction-effects between conditions[b] and student characteristics

	Pretest score						**Phase 1 (Growth from pre- to posttest)**						**Phase 2 (Growth from pre- to posttest)**					
	Control con. β_0	**Girl β_3**	**RPMM β_6**	**SGMM β_7**	**Girl. RPMM β_{12}**	**Girl. SGMM β_{13}**	**Control con. β_1**	**Girl β_4**	**RPMM β_8**	**SGMM β_9**	**Girl. RPMM β_{14}**	**Girl. SGMM β_{15}**	**Control con. β_2**	**Girl β_5**	**RPMM β_{10}**	**SGMM β_{11}**	**Girl. RPMM β_{16}**	**Girl. SGMM β_{17}**
Gender																		
Informative text	0.147 (0.086)	0.151 (0.086)	0.099 (0.121)	-0.072 (0.126)	-0.197 (0.121)	0.033 (0.120)	-0.057 (0.069)	-0.074 (0.11)	0.067 (0.103)	0.687 (0.103) *	0.404 (0.155) *	0.202 (0.153)	0.046 (0.069)	0.029 (0.111)	-0.049 (0.102)	-0.337 (0.103) *	-0.095 (0.155)	-0.012 (0.153)
Graphical design	0.289 (0.100) *	0.040 (0.101)	0.160 (0.141)	0.383 (0.147) *	0.049 (0.142)	-0.033 (0.141)	0.334 (0.083) *	-0.232 (0.133)	1.612 (0.124) *	2.107 (0.124) *	0.248 (0.187)	0.387 (0.185) *	0.232 (0.083) *	0.109 (0.134)	-0.275 (0.124) *	-0.422 (0.124) *	-0.239 (0.187)	-0.138 (0.185)
Grade																		
	Control con. β_0	**Sixth β_3**	**RPMM β_6**	**SGMM β_7**	**Sixth . RPMM β_{12}**	**Sixth. SGMM β_{13}**	**Control con. β_1**	**Sixth β_4**	**RPMM β_8**	**SGMM β_9**	**Sixth . RPMM β_{14}**	**Sixth . SGMM β_{15}**	**Control con. β_2**	**Sixth β_5**	**RPMM β_{10}**	**SGMM β_{11}**	**Sixth . RPMM β_{16}**	**Sixth . SGMM β_{17}**
Informative text	0.246 (0.108) *	-0.089 (0.138)	-0.042 (0.146)	-0.251 (0.156)	0.104 (0.179)	0.396 (0.191) *	-0.153 (0.076) *	0.134 (0.107)	0.384 (0.111)	0.621 (0.111) *	-0.238 (0.153)	0.261 (0.152)	0.028 (0.076)	0.056 (0.108)	0.040 (0.111)	-0.161 (0.111)	-0.246 (0.153)	-0.316 (0.152) *
Graphical content	0.231 (0.111) *	0.063 (0.143)	0.139 (0.150)	0.310 (0.160)	0.241 (0.186)	0.143 (0.197)	0.259 (0.085) *	-0.125 (0.120	1.470 (0.124) *	1.214 (0.124) *	0.022 (0.171)	0.477 (0.169) *	0.406 (0.085) *	-0.217 (0.120)	-0.481 (0.124) *	-0.356 (0.124) *	0.217 (0.171)	-0.063 (0.169)

Note. [a] Significant parameters are indicated with an asterisk (*), standard error estimates are placed between brackets; [b] RPMM condition= researcher-provided mind map condition, SGMM condition= student-generated mind map condition.

Note. Model equation

$y_{ijk} \sim N(\chi B,\Omega)$

$y_{ijk} = \beta_{0\ ijk}\,CONS + \beta_1.p1_{IJK} + \beta_2.p2_{ijk} + \beta_3.girl + \beta_4 girl.p1_{ijk} + \beta_5\ girl.p2_{ijk} + \beta_6\ RPMM_k + \beta_7 SGMM_k + \beta_8 RPMM.p1_{\ ijk} + \beta_9 SGMM.p1_{\ ijk} + \beta_{10}\ RPMM.p2_{\ ijk} + \beta_{11}\ RPMM.p2_{\ ijk} + \beta_{12}\ girl.RPMM_{jk} + \beta_{13}\ girl.SGMM_{jk} + \beta_{14}\ girl.RPMM.p1_{ijk} + \beta_{15}\ girl.SGMM.p1_{ijk} + \beta_{16}\ girl.RPMM.p2_{ijk} + \beta_{17}\ girl.RPMM.p2_{ijk}$

$\beta_{0\ ijk} = \beta_0 + v_{\ ok} + e_{\ 0jk} + e_{\ 0\ ijk}$

$[\ v_{\ ok}\ ] \sim N(0,\Omega_v) : \Omega_v = [\sigma^2_{v\ 0}]$

$[\ u_{\ ojk}\ ] \sim N(0,\Omega_u) : \Omega_u = [\sigma^2_{u\ 0}]$

$[\ e_{\ oijk}\ ] \sim N(0,\Omega_e) : \Omega_e = [\sigma^2_{e\ 0}]$

Discussion

This study builds on the importance of unfolding graphical summarization skills, enabling students to represent large texts in a more condensed and memorable form. In this respect, the influence of a developed graphical summarization strategy instruction incorporating either researcher-provided or student-generated mind maps on students' graphical summarization skills in late elementary education was investigated. Moreover, some potential influencing factors were explored.

Discussion of the findings

To investigate the first research question, "Can the developed graphical summarization strategy instruction be used to stimulate students' graphical summarization skills?", experimental condition students' growth in graphical summarization skills was contrasted with control condition students' growth. Results provide evidence for the effectiveness of both graphical summarization strategy instruction approaches, as the experimental students outperform control students on informative text traces, graphical design, and graphical content. At retention test, sustained effects were found after the intervention period was finished, with the exception of researcher-provided mind map condition students' informative text score, which did not differ from control students' score at retention test. This result corroborates previous research showing that instruction in summarization skills is fruitful (Broer et al., 2002; Merchie & Van Keer, 2013; Westby et al., 2010), and furthermore provides clear evidence for both developed teacher-delivered graphical summarization strategy instructions.

To answer the second research question, concerning the differential impact of the instructional approach (i.e., working with either researcher-provided or student-generated mind maps) on students' graphical summarization skills, experimental condition students were contrasted against each other. The greatest gains were found for students in the student-generated mind map condition, with regard to the quality of their informative text traces and graphical design. This indicates that student-generated mind map condition students paid more careful attention to text selection and organization processes prior to graphical summary construction.

Although those strategic activities during pre-writing (i.e., scanning, reading, and highlighting text) were explicitly addressed in both instructional approaches, results illustrate a more autonomous strategy application for student-generated mind map condition students. A possible explanation for this relates to the fact that researcher-provided mind map condition students often inspected the researcher-provided map to use it as a scaffold when structuring text during the lessons, but experienced difficulty with applying this strategy once the scaffold was removed during the test moments (Chang et al., 2002). Student-generated mind map condition students, not supported by a provided map, were challenged to structure the text more independently. This line of reasoning might also account for the growth in students' graphical design, as student-generated mind map condition students actively practiced the integration of specific graphical design principles. Detailed analyses of the subcomponents of the graphical design, however, revealed a larger growth for researcher-provided mind map condition students regarding the connection of images to words. Possibly, seeing and interpreting various images included in the researcher-provided mind map condition learner materials evoked students' own mental imagery processes more during an independent task. Although student-generated mind map condition students were also prompted to include images in their maps, this was only practiced briefly during two assignments throughout the lessons. Therefore, it is advisable to devote more explicit strategy instruction to this specific graphical design principle, bearing in mind the beneficial effects of these mental imagery processes on learning (Anderson & Hidde, 1971; Leopold et al., 2013). Further, no significant differences were found regarding the graphical content between researcher-provided and student-generated mind map condition students. Consequently, researcher-provided mind map condition students seemed to have also learned a lot in this respect from the worked examples. However, detailed analyses on the subcomponents of the graphical content revealed that student-generated mind map condition students obtained higher scores on choosing a relevant blanket term, an essential aspect during construction, since well-chosen blanket terms provide more opportunities to further elaborate on. Also in this respect, student-generated mind map condition students had more practice opportunities since they had to construct the mind map themselves. The time spent on strategy instruction and the intervention was however the same in both experimental conditions. Overall, students from the student-generated mind map condition obtained the greatest gains, as they coordinated the strategic activities integrated in the graphical summarization strategy more autonomously in a goal-oriented way. It might be possible, however, that in order to internalize some powerful aspects of graphical summarization strategy instruction (e.g., connecting images to words), students might benefit from combining more practice opportunities together with some provided worked examples.

In a third research question, the relationship between the instructional approach and students' characteristics was investigated. The main influencing student characteristics were gender and grade. Girls in the researcher-provided mind map condition showed a significantly larger growth than boys in this condition on informative text score. Girls in the student-generated mind map condition obtained a higher graphical design score than boys in this condition. Possibly, further qualitative research would provide researchers with the opportunity to gain more insight into why exactly these gender differences occur. As for students' grade, sixth graders showed a significantly larger growth in the student-generated mind map condition on informative text score and graphical content. Probably, sixth graders are already more mature and had in this respect more prior knowledge of how to independently conduct these strategic activities during pre-writing and construction. Surprisingly, no significant aptitude-by-treatment interactions were found with regard to home language and general achievement level. This finding was rather unexpected, as previous research indicated that low achievers or students with lower verbal abilities might profit least from strategy instruction (Hattie et al., 1996; Nesbit & Adesope, 2006). Although we must be aware of the fact that only a limited number of nonnative speakers were involved in this study, this finding is encouraging, as it indicates that all students benefited equally from the graphical summarization strategy instructions, regardless of their home language or general achievement level.

Limitations and suggestions for future research

As with any other study, this investigation is associated with some limitations. Four limitations are explicitly translated into questions warranting further investigation. First, graphical summarization was mainly approached through a product-oriented perspective. That is, students' graphical summarization skills were evaluated based on the quality of the overt observable traces in their texts and created products. Although the trace analysis of the informative texts provided an indication of students' preparatory processes for graphical summary construction and the attempt to map the pre-writing phase is an asset of this study, less is known about the more covert, non-observable mental strategies before, during, and after summarization. In this respect, it would be interesting to explore how students gradually construct their graphical summary (e.g., do they first search for blanket terms and elaborate on them subsequently?). In-depth analyses of the construction process of the most successful students might reveal interesting findings. Additionally, it was very difficult in this study to gain insight into the post-writing phase of graphical summarization. Did students review their graphical summary, or add keywords afterwards? Therefore, the present study hopes to inspire future research to complement our findings by providing answers to these questions. More particularly, it is advised that the graphical summarization process should be studied by means of on-line methods such as analyzing students' pen and eye movements (Alamargot, Chesnet, Dansac, & Ros, 2006; Alamargot et al., 2010; Merchie & Van Keer, 2014). Further, students' cognitive processes during mapping can be revealed by applying the think-aloud methodology during mapping (Hilbert & Renkl, 2008) or retrospective self-reports (Schellings & Broekkamp, 2011), which might be more feasible for younger students. Previous research has already pointed at the difficulty pre-adolescents experience with thinking aloud during the graphical summary construction process (Merchie & Van Keer, 2014).

A second limitation of this study is the unexplored relationship between students' graphical summarization skills and learning performance. This exploration lay beyond the scope of the present study. However, after developing an effective graphical summarization strategy instruction and verifying whether students can adequately apply the taught strategy, the next step is investigating how students' graphical summarization techniques translate into better learning, that is, how their high-quality graphical summaries function as learning tools to influence aspects of textual learning (i.e., sustained retention, comprehension, near and far transfer) (Dexter & Hughes, 2011; Hilbert & Renkl, 2008). In this respect, students can be asked to study an instructional text either with prompted graphical summarization strategy use or without prompted use, to investigate whether this strategy is produced spontaneously (Veenman, 2011). In addition, more specific experimental studies could focus on how the different design principles included in the graphical summary (e.g., incorporating colors, figures, shapes, radial structure, arrows) contribute precisely to the effectiveness of the graphical summaries (Hall & Sidio-Hall, 1994; Wallace et al., 1998).

Third, this study focussed on the direct comparison of two distinct instructional approaches. It seems fruitful however to build on the obtained results in a further design-based study. In the current study, using researcher-provided mind maps during instruction affected the use of images in students' graphical summaries significantly more than applying student-generated mind maps. By means of a design-based research approach (e.g., Barab & Squire, 2004), effects could be investigated of incorporating pre-made mind maps into the student-generated mind map instructional approach, since a number of studies point at the effectiveness of gradually fading worked-out steps to foster learning and transfer (e.g., Atkinskon, Renkl, & Merrill, 2003; Renkl, Atkinson, Maier, & Staley, 2002). In this respect, based on design-based research findings, the effects of an instructional mind map approach to stimulate graphical summarization skills can be optimized.

Fourth, future research, focusing on a larger number of schools, should be encouraged to investigate the school level as an additional hierarchical level (i.e., teachers having the same principal and sharing the same experiences in a school) in the multilevel analyses, as this might influence teachers' project commitment and sustainability (Mishna, Muskat, & Cook, 2012).

Contributions and implications for practice

Various aspects make this study unique with respect to other studies. Theoretically, this investigation combines insights derived from different research areas related to self-regulated learning, reading to learn (Mateos et al., 2008), writing to learn (e.g., Alamargot et al., 2006), learning strategy research, summarization instruction (e.g., Westby et al., 2010), working with graphic organizers (e.g., Nesbit & Adesope, 2006; Vekiri, 2002), and intervention research (e.g., Dignath et al., 2008). Methodologically, a teacher-delivered intervention was included over a relatively long period of time, whereby two instructional approaches for initiating graphical summarization skills were incorporated and compared in large-scale research. The design was complemented with a control group, providing an objective comparison baseline. Furthermore, retention test measurement allowed insight to be gained into the interventions' short-term and long-term effects. The endurance of the acquired strategy was analyzed by means of multilevel analysis explicitly taking into account students' hierarchical nesting in classes. Further, the developed analytic scoring rubrics, showing good to excellent interrater reliabilities, can be used in future research studying graphical summarization.

Furthermore, this study carries important implications for educational practice, as it investigates an instructional technique (i.e., mind mapping), which is already frequently applied in class, but misses clear evidence-based underpinnings. In this respect, this study demonstrated the effectiveness of a developed graphical summarization strategy instruction implemented in late elementary education for initiating and stimulating graphical summarization skills. More precisely, teachers are recommended to follow the subsequent identified strategic activities as presented in Table 1, i.e., in the pre-writing phase (1) scan and read the text, clarify incomprehension, (2) apply text marking strategies to structure the text information, in the construction phase (3) construct your graphical summary, taking into account graphical design- and content-specific elements, and in the post-writing phase (4) review and revise your text and graphical summary. In this strategy instruction, the importance of consequent stimulation and supervision is stressed. This study has shown that overall, all students benefited equally well from this strategy instruction. Working with student-generated maps seemed most promising in stimulating graphical summarization skills. It is advised, however, that worked examples should be incorporated when wanting to initiate specific cognitive processes such as mental imagery. Furthermore, teachers can use the developed analytic scoring rubrics as an assessment tool, either summatively (e.g., Westby et al., 2010) as a summary reflects students' text comprehension (i.e., are students able to determine what is more and less important, can they make inferences between ideas in the text and define text relationships?) or formatively, i.e., as a means to provide students' feedback on their graphical summary process and regulate their own learning (Panadero & Jonsson, 2013).

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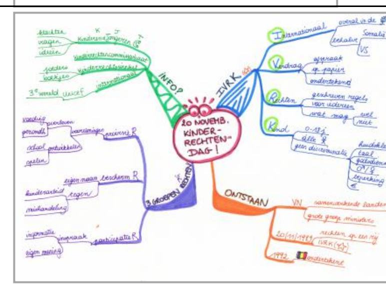
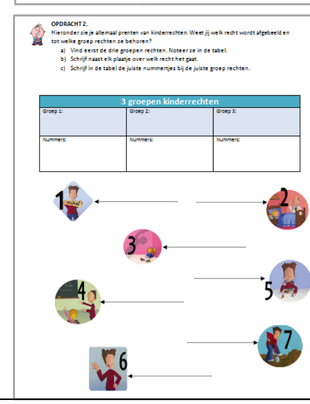
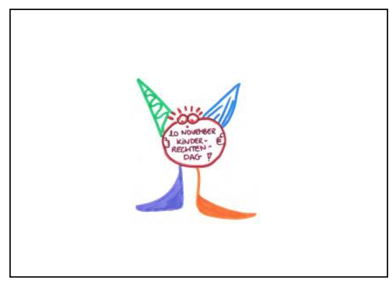
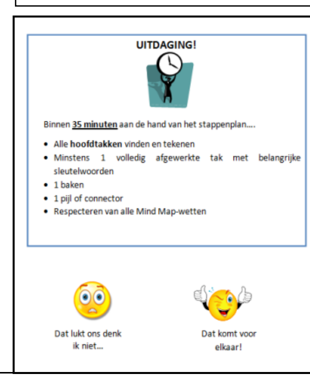
Appendix A

Example of a classroom assignment (related to a text concerning children's rights) in experimental condition 1: Graphical summarization strategy instruction with researcher-provided mind maps. The total lesson duration is 50 minutes.

Phases	Essential cognitive processes with sequentially ordered activities		Worksheets
Pre-writing or planning phase		Getting an overview: Scan and read the text, clarify incomprehension	
		Text selection and organization: Highlight and structure important text information	
Construction phase		Text transformation: Mind map assignment to be completed with researcher-provided mind map	
		• Search for the three groups of children's rights in the mind map and write them down in the table. • Which rights are the pictures illustrating? Write them down. • Match the rights' numbers to the corresponding group in the table.	
Post-writing or reviewing phase		Product and process evaluation: Reviewing and revising assignment solution	

Appendix B

Example of a classroom assignment (related to a text concerning children's rights) in experimental condition 2: Graphical summarization strategy instruction with student-generated mind maps. The total lesson duration is 50 minutes.

Phases	Essential cognitive processes with sequentially ordered activities	Worksheets
Pre-writing or planning phase	 Getting an overview: Scan and read the text, clarify incomprehension  Text selection and organization: Highlight and structure important text information	 20 november: Kinderrechtendag!
Construction phase	 Text transformation: Mind map assignment to construct a student-generated map Challenge: Can you complete the following tasks within the next 35 minutes? • Find all main branches. • Elaborate at least one main branch with related sub-branches using important keywords. • Include 1 cluster, 1 arrow or connector. • Respect all specific mind map characteristics. • Indicate whether or not you think the challenge will succeed.	  UITDAGING! Binnen 35 minuten aan de hand van het stappenplan.... • Alle **hoofdtakken** vinden en tekenen • Minstens 1 volledig afgewerkte tak met belangrijke sleutelwoorden • 1 baken • 1 pijl of connector • Respecteren van alle Mind Map-wetten Dat lukt ons denk ik niet... Dat komt voor elkaar!
Post-writing or reviewing phase	 Product and process evaluation: Reviewing and revising student-generated map	

Appendix C

Scoring rubric for the traces in the informative text

Informative text traces					
	0	1	2	3	4
(Sub)title markings	Not applicable (no text markings)	Only the title is marked	Marked some or all subtitles	Marked title and some subtitles	Marked title and subtitles
Figure markings	Not applicable (no figure markings)	Markings in one figure	Markings in several figures	Markings and/or annotation in several figures	A combination of markings and annotations in one or more figures
Distinguishing main and sub ideas by means of different colors	Not applicable (no text markings)	Only one color is used during highlighting	There is more than one color used, but the distinction between main and sub ideas is not clear	Different colors are used, however the distinction between main and sub ideas is sometimes still made inconsistently Or: Every paragraph is marked with a different color, but not always consistently	There is consistent use of different colors throughout the text, reflecting the differences between main and sub ideas Or: Every paragraph is consistently marked with a different color
Color quantity	Not applicable (no text markings)	1 color used	2 colors used	3 colors used	More than 4 colors used

Appendix D

Scoring rubric for the graphical summary[a,b]

Graphical design					
	0	1	2	3	4
Branch dimension: The main branches are thicker than the sub-branches	Not applicable (no GS)	Not respected	Generally not respected	Mainly respected	Respected
Letter dimension: On the main branches capitals are used, on the sub-branches small letters are used	Not applicable (no GS)	Not respected: use of capitals and small letters is mixed up	Generally not respected: main branches mainly in small letters, sub-branches mainly in capitals	Mainly respected	Respected
Color use: For every branch, a different color is used	Not applicable (no GS)	No use of color	Use of different colors within a branch	Mainly correct color use or mind map temporally made in pencil to color afterwards	Every main branch and associated sub-branches are drawn in the same color
Readability	Not applicable (no GS)	GS is not readable without turning the page	GS is only partly readable without turning the page	The content of the GS is mainly readable without turning the page	The GS is readable without turning the page
Keyword place	Not applicable (no GS)	None of the keywords are placed on the branches	On occasion, keywords are placed on the branches	Keywords are mainly positioned on the branches	All keywords are positioned on the branches
Inclusion of images	Not applicable (no GS)	No use	Irrelevant or unclear use	Correct and creative use, not always relevant	Correct, creative, and relevant use
Radial structure	Not applicable (no GS)	Radial structure is not respected	Radial structure is generally not respected	Radial structure is mainly respected	Radial structure is respected

Graphical content					
	0	1	2	3	4
Inclusion of arrows	Not applicable (no GS)	No use	Incorrect use	Mainly correct and relevant use	Correct and relevant use
Choice of the keywords	Not applicable (no GS)	Sentences are completely copied/long branches	Sentences are mainly copied, too many keywords on a branch or irrelevant keywords	keywords are mainly relevant and are most of the time nouns and verbs	Keywords are relevant, consist of nouns and verbs, good length of the branches
Content coverage	Not applicable (no GS)	No or little content coverage	Average content coverage	Good content coverage	Almost complete content coverage
Association	Not applicable (no GS)	Words in a branch do not match	Words in a branch do not really match and/or are wrongly associated	Words in a branch match and are mainly well associated	Words in a branch match and are correctly associated
Choice blanket term	Not applicable (no GS)	Keywords are not relevant or not general enough	Keywords are mainly not relevant or not general enough	Keywords are mainly relevant and general enough	Keywords are relevant and general enough
Deepening	Not applicable (no GS)	No or little deepening: No or just a few main branches without many additional associations	Low deepening: Only a few main branches, wrong ordering between most and less complex information	Moderate deepening: Some highly elaborated branches with hierarchically correctly made associations	Strong deepening: Almost all main branches are elaborated in depth by associating hierarchically correctly the text's main and sub ideas

Note. [a] GS=graphical summary. [b] This rubric is based on a previously developed scoring rubric (Merchie & Van Keer, 2013).

Appendix E

Detailed summary of the model estimates[a] for the three-level analysis of the informative text subcomponents[b] , graphical design subcomponents, and graphical content subcomponents[c] for the three conditions[d]

	Fixed part									Random part	
Informative text traces sub-components	**Pretest score**			**Phase 1 (Growth from pre- to posttest)**			**Phase 2 (Growth from posttest to retention test)**			**Variances at the three levels[c] $\sigma^2(SD)$**	**Proportion of the variance at the three levels**
	RPMM Condition β_3	**SGMM Condition β_4**	**Control condition Intercept β_0**	**RPMM Condition β_5**	**SGMM Condition β_6**	**Reference category: Control condition β_1**	**RPMM Condition β_7**	**SGMM Condition β_8**	**Reference category: Control condition β_2**		
(Sub)title markings	0.033 (0.153)	-0.043 (0.161)	0.165 (0.112)	0.310 (0.115)*	1.090 (0.113)*	-0.074 (0.081)	-0.067 (0.115)	-0.484 (0.114)*	0.063 (0.081)	3 0.138(0.038)* 2 0.126(0.024)* 1 0.731(0.029)*	13.87%* 12.66%* 73.47%*
Figure markings	-0.003 (0.026)	0.016 (0.026)	0.038 (0.019)	0.086 (0.032)*	0.070 (0.032)*	-0.023 (0.023)	-0.063 (0.032)	-0.066 (0.032)*	0.014 (0.023)	3 0.001(0.001) 2 0.007(0.002) 1 0.054(0.002)*	1.61% 11.29% 87.10%*
Color quantity	-0.009 (0.143)	-0.082 (0.152)	0.300* (0.105)	0.328 (0.102)*	1.026 (0.101)*	-0.120 (0.072)	-0.134 (0.102)	-0.478 (0.101)*	0.075 (0.072)	3 0.118(0.033)* 2 0.106(0.019)* 1 0.581(0.023)*	14.66%* 13.17%* 72.17%*
Disting main and sub with colors	0.040 (0.155)	-0.044 (0.163)	0.300* (0.114)	0.308 (0.115)*	0.938 (0.114)*	-0.125 (0.081)	-0.112 (0.115)	-0.329 (0.114)*	0.075 (0.081)	3 0.135(0.037)* 2 0.100(0.022)* 1 0.720(0.029)*	14.14%* 10.47%* 75.39%*

Note. [a] Significant parameters are indicated with an asterisk (*), standard error estimates are placed between brackets; [b] More information on the scored components can be found in Appendix C [c] More information on the scored components can be found in Appendix D [d] RPMM condition= researcher-provided mind map condition, SGMM condition= student-generated mind map condition; [e] 3= class-level variance, 2 = student-level variance, 1 = measurement occasion-level variance in the fully unconditional three-level null models.

Note. Model equation

$y \sim \mathrm{N}(X\mathrm{B},\Omega)$

$y_{ijk} = \beta_{0\,ijk}\,\mathrm{CONS} + \beta_1.\mathrm{p1}_{IJK} + \beta_2.\mathrm{p2}_{ijk} + \beta_3\,\mathrm{RPMM}_k + \beta_4\,\mathrm{SGMM}_k + \beta_5\,\mathrm{RPMM.p1}_{\,ijk} + \beta_6\,\mathrm{SGMM.p1}_{\,ijk} + \beta_7\,\mathrm{RPMM.p2}_{\,ijk} + \beta_8\,\mathrm{SGMM.p2}_{\,ijk}$

$\beta_{0\,ijk} = \beta_0 + v_{\,ok} + e_{\,0jk} + e_{\,0\,ijk}$

$[\,v_{\,ok}\,] \sim \mathrm{N}(0,\Omega_v) : \Omega_v = [\sigma^2_{v\,0}]$

$[\,u_{\,ojk}\,] \sim \mathrm{N}(0,\Omega_u) : \Omega_u = [\sigma^2_{u\,0}]$

$[\,e_{\,oijk}\,] \sim \mathrm{N}(0,\Omega_e) : \Omega_e = [\sigma^2_{e\,0}]$

Graphical design subcomponents	Fixed part									Random part		
	Pretest score			Phase 1 (Growth from pre- to posttest)			Phase 2 (Growth from posttest to retention test)			Variances at the three levels[c] σ^2(*SD*)		Proportion of the variance at the three levels
	RPMM Condition β_3	SGMM Condition β_4	Control condition Intercept β_0	RPMM Condition β_5	SGMM Condition β_6	Reference category: Control condition β_1	RPMM Condition β_7	SGMM Condition β_8	Reference category: Control condition β_2			
Thick/tin	0.140	0.228	0.197	2.383	3.194	0.139	-0.566	-0.505	0.210	3	0.861(0.211)*	41.90%*
	(0.148)	(0.156)	(0.108)	(0.123)*	(0.121)*	(0.087)	(0.123)*	(0.122)*	(0.087)*	2	0.000(0.000)	0%
										1	1.194(0.039)*	58.10%*
Letters	0.105	0.231	0.186	0.754	2.470	0.142	-0.188	-0.626	0.198	3	0.488(0.121)*	36.64%*
	(0.122)	(0.128)	(0.089)*	(0.102)*	(0.101)*	(0.072)*	(0.102)	(0.101)*	(0.072)*	2	0.022(0.021)	1.65%
										1	0.822(0.033)*	61.71%*
Color	0.145	0.203	0.241	2.268	2.802	0.177	-0.464	-0.364	0.193	3	0.695(0.172)*	38.04%*
	(0.126)	(0.131)	(0.091)*	(0.117)*	(0.116)*	(0.083)*	(0.117)*	(0.116)*	(0.083)*	2	0.000(0.000)	0%
										1	1.132(0.037)*	61.96%*
Symbols	0.111	0.187	0.205	1.156	0.898	0.123	-0.219	-0.156	0.198	3	0.168(0.044)*	21.08%*
	(0.109)	(0.114)	(0.080)*	(0.097)*	(0.096)*	(0.068)	(0.097)*	(0.096)	(0.069)*	2	0.075(0.017)*	9.41%*
										1	0.554(0.022)*	69.51%*
Readability	0.289	0.791	0.622	1.584	1.759	0.482	-0.312	-0.656	0.529	3	0.771(0.194)*	29.50%*
	(0.249)	(0.264)*	(0.183)*	(0.176)*	(0.174)*	(0.124)*	(0.176)	(0.174)*	(0.124)*	2	0.077(0.046)	2.95%
										1	1.765(0.071)*	67.55%*
Place Keywords	0.261	0.350	0.201	2.376	3.106	0.164	-0.223	-0.390	0.258	3	0.964(0.236)*	46.55*
	(0.136)	(0.143)*	(0.099)*	(0.113)*	(0.111)*	(0.079)*	(0.113)*	(0.112)*	(0.080)*	2	0.000(0.000)	0%
										1	1.107(0.036)*	53.45%*
Structure	0.248	0.581	0.487	1.493	1.726	0.470	0.722	0.666	0.349	3	0.524(0.133)*	25.49%*
	(0.200)	(0.211)*	(0.147)*	(0.159)*	(0.157)*	(0.112)*	(0.159)*	(0.157)*	(0.112)*	2	0.087(0.039)*	4.23%*
										1	1.445(0.058)*	70.29%*

Graphical content subcomponents	Fixed part: Pretest score			Phase 1 (Growth from pre- to posttest)			Phase 2 (Growth from posttest to retention test)			Random part: Variances at the three levels[c] $\sigma^2(SD)$		Proportion of the variance at the three levels
	RPMM Condition β_3	SGMM Condition β_4	Control condition Intercept β_0	RPMM Condition β_5	SGMM Condition β_6	Reference category: Control condition β_1	RPMM Condition β_7	SGMM Condition β_8	Reference category: Control condition β_2			
Arrows	0.127 (0.071)	0.212 (0.075)*	0.185 (0.052)*	0.569 (0.054)*	0.520 (0.053)*	0.143 (0.038)*	-0.180 (0.054)*	-0.259 (0.053)	0.193 (0.038)*	3	0.065(0.017)*	26.64%*
										2	0.013(0.005)*	5.33%*
										1	0.166(0.004)*	68.03*
Choice key words	0.352 (0.161)*	0.477 (0.170)*	0.373 (0.118)*	1.597 (0.129)*	1.536 (0.128)*	0.265 (0.091)*	-0.498 (0.130)*	-0.370 (0.128)*	0.392 (0.091)*	3	0.469(0.118)*	30.04%*
										2	0.084(0.028)*	5.38%*
										1	1.008(0.040)*	64.57%*
Content coverage	0.122 (0.111)	0.263 (0.117)*	0.208 (0.081)*	1.169 (0.083)*	1.168 (0.082)*	0.153 (0.059)*	-0.242 (0.084) *	-0.0453 (0.083)*	0.188 (0.059)*	3	0.206(0.052)*	29.77*
										2	0.046(0.013)*	6.65%*
										1	0.440(0.018)*	63.58%*
Associations	0.452 (0.160)	0.660 (0.169)*	0.302 (0.118)*	1.547 (0.126)*	1.385 (0.124)*	0.235 (0.089)*	-0.658 (0.126)*	-0.579 (0.124)*	0.450 (0.089)*	3	0.482(0.120)*	33.61%*
										2	0.017(0.023)	1.19%
										1	0.935(0.037)*	65.20%*
Blanket term choice	0.334 (0.154)*	0.437 (0.161)*	0.285 (0.112)*	2.488 (0.137)*	2.744 (0.135)*	0.288 (0.096)*	-0.307 (0.137)*	-0.311 (0.135)*	0.309 (0.097)*	3	0.957(0.235)*	41.11%*
										2	0.000(0.000)	0%
										1	1.371(0.045)*	58.89%*
Deepening	0.209 (0.102)*	0.276 (0.104)*	0.224 (0.075)*	1.499 (0.086)*	1.527 (0.085)*	0.153 (0.061)*	-0.347 (0.086)*	-0.472 (0.08*5)	0.249 (0.061)*	3	0.304(0.075)*	36.58%*
										2	0.010(0.013)	1.20%
										1	0.517(0.021)*	62.22%*

7

From text to graphical summary: A product- and process-oriented assessment to explore the evolution in fifth and sixth graders' dynamic construction

This chapter is based on:

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Chapter 7
From text to graphical summary: A product- and process-oriented assessment to explore the evolution in fifth and sixth graders' dynamic construction

Abstract

Working with graphical summaries is promising to assist students' text-based learning and provide teachers with an assessment method for students' text processing skills. This study (1) investigates the impact of an instructional intervention including either researcher-provided or student-generated mind maps on students' evolution in graphical summary products and ongoing summarization processes, (2) provides an in-depth exploration of students' construction phases. Eighteen fifth and sixth graders participated. Data were analyzed from a product- and process-oriented perspective. Results show little evolution in the time spent on the pre- and post-writing phase and no significant differences between the experimental and control condition. Experimental condition students evolve significantly more than control condition students as to the quality of the graphical summary products. In-depth construction phase exploration revealed five elaboration approaches to construct a graphical summary and the possibility to verify different construction steps. Future research is encouraged to complement pen movement data with eye-tracking or retrospective interviews. Teachers are advocated to apply the joint assessment of both graphical summary product and process data into their classroom practices.

Introduction

Being able to strategically process, manipulate, and condense textual material becomes increasingly important in an information society, wherein students are overwhelmed with large amounts of to-be-learnt informational texts. Education is expected to prepare students towards this text-based learning, which is reflected in educational standards stressing the importance of self-regulated learning. These 'learning to learn'-skills are considered a key competence in the 21st century (Hoskins & Crick, 2010). Within this broad self-regulated learning strategy repertoire, summarization strategies become of major importance at the end of elementary education. From then on, the focus shifts from learning to read and write towards reading and writing to learn to obtain instructional knowledge from texts (Newell, 2006). Consequently, the acquisition of summarization strategies becomes crucial for students to handle the increasing amounts of instructional texts throughout their educational carrier.

Writing a summary is regarded as a powerful strategy helping students to process informative texts and to condense them to their essence (Broer, Aarnoutse, Kieviet, & Van Leeuwe, 2002; Friend, 2001). It is believed that summarizing texts leads to deep text processing, as it prompts essential learning strategies such as elaboration (e.g., paraphrasing information or connecting it to prior knowledge) and organization (e.g., text reorganization), which evoke higher levels of cognitive processing (Bangert-Drowns, Hurley, & Wilkinson, 2004; Weinstein & Mayer, 1986; Weinstein, Jung, & Acee, 2011). Although a summary can take many forms (e.g., linear outline, matrices, or maps), especially summaries requiring graphical text reorganization are found to be beneficial in students' text processing and learning (Dansereau & Simpson, 2009; Nesbit & Adesope, 2006). These 'graphical summaries', are defined in this study as visually coherent and hierarchically organized spatial structures of linear multi-paragraphs text.

Despite the importance of graphical text summarization, many - especially young - students still turn to the more counterproductive copy-and-delete summarization method (Brown & Day, 1983; Friend, 2001). They merely copy sentences linearly, and do not paraphrase or reorganize text. Their summarization is rather a simple text selection process instead of a text synthesis process, whereby ineffective strategies are employed during reading (e.g., irrelevant information is regarded as main idea information) or writing (i.e., the information is not condensed). Explicit instruction in graphical summarization strategies seems thus necessary, as these students lack essential cognitive and metacognitive processes to create a graphical summary (Garner, 1990; Friend, 2001; Mateos, Martin, Villalon, & Luna, 2008).

Instruction in graphical summarization strategies

A first important step in developing an instruction in graphical summarization strategies is identifying a solid, well-founded theoretical base. Based on a literature review on text-learning research in general, summarization strategies in particular, and writing-to-learn research (e.g., Alamargot, Plane, Lambert, & Chesnet, 2010; Berninger, Fuller, & Whitaker, 1996; Flower & Hayes, 1981; Friend, 2001; Schlag & Ploetzner, 2011), essential phases and cognitive operations of summarizing can be identified. Overall, summarization occurs during the construction of a dual-level cognitive text representation while passing through three phases of pre-writing, construction, and post-writing (Alamargot et al., 2010; Berninger et al., 1996; Flower & Hayes, 1981; Friend, 2001). The main goal of the pre-writing or planning phase is to build a micro-level text representation to decide which text information should be included in the summary. Here, students focus on the text's surface-structure such as text-based signals, structural cues, and explicit markers such as subtitles or figures. During scanning and reading, students' attention is guided towards 'repeated references' (Friend, 2001) or 'argument repetitions' (van Dijk & Kintsch, 1983) that is, the more an idea is referred to in the text, the more important it is. Students can already structure the to-be-summarized text content by marking or underlining main- and sub-ideas. In the construction phase, students derive the texts' macro structure, that is a terse representation of the most important information. Here students engage in the cognitive process of 'generalization', to identify the hierarchical arrangement of text ideas

(Friend, 2001). Three summary-specific mental operations are performed: deletion (i.e., leaving out unnecessary, trivial, or off-the-subject information), generalization (i.e., finding blanket terms which pull different ideas together), and construction (i.e., transcribing the main- and sub-ideas into a coherent structure) (Friend, 2001; van Dijk & Kintsch, 1983). In the final post-writing or revision phase, several cognitive processes are in interplay to critically reread, evaluate, and revise the graphical summary when necessary (McCutchen, 2006) Several revision actions can be undertaken (e.g., verifying the understandability, readability or completeness of the graphical summary).

Given the importance of graphical text reorganization, an accessible spatial format was selected to include in the instruction of graphical summarization strategies. Two important reasons were decisive to use mind maps (Buzan, 1974; Buzan, 2005) during strategy instruction in the present study. First, mind maps' design and spatial content arrangement lean themselves perfectly for graphical text summarization. Mind maps are typified by specific design-principles (e.g., including thick and thin branches, capitals and small letters, images), which are theoretically and empirically underpinned (e.g., Anderson & Hidde, 1971; Haber, 1970; O'Donnell, Dansereau, & Hall, 2002). These principles are strictly related to the hierarchical text representation. The text's main ideas are written in capital letters on thick branches directly related to the central theme, the text's super- and subordindate ideas are written in small letters on thin sub-branches. Different text relationships can be visualized by adding arrows or connectors (Buzan, 2005). This format is very accessible for elementary school students and differs greatly from the more constrained top-down linear arrangement of concept maps wherein explicit connective-terms must be used between concepts (Novak, 2002). A second important reason to include mind maps into strategy instruction is related to important questions regarding their instructional use in classrooms. Although mind maps are already frequently employed in educational practice, there is a lack of evidence-based classroom research, especially in elementary education. This leads to many unanswered questions: How precisely should mind maps be integrated into strategy instruction? Which concrete guidelines can be formulated to spatially arrange text information in this way? It can be hypothesized that different instructional approaches such as working with either researcher-provided or student-generated maps might influence students' graphical summarization skills (Stull & Mayer, 2007). In this respect, researcher-provided mind maps could serve as scaffolds, showing students how linear text information is transformed through the phases of pre-writing, construction, and post-writing. On the other hand, students might learn more from immediately conducting all strategic activities by themselves in creating student-generated maps (Stull & Mayer, 2007; Leopold et al., 2013). In this respect, specific mind map construction guidelines are already formulated to guide students' map construction (e.g., define and draw all main branches, elaborate on each main branch subsequently) (Buzan, 2004; Hoffman, 2001). However, only limited empirical evidence exists on how students spontaneously construct mind maps without these specific guidelines an whether different elaboration approaches lead to qualitatively different summaries.

Product- and process-oriented assessment of graphical summarization skills

Graphical summaries can thus serve as important text-processing and learning tools for students. However, they can also function as assessment tools for researchers and teachers, as they reflect students' mental structures and externalize their current knowledge state (Hilbert & Renkl, 2008; Malmberg, Jarvenoja, & Jarvela, 2010). To fully assess students' graphical summarization skills, assessment should be carried out from a product-oriented perspective (i.e., assessing the final product) and a process-oriented perspective (i.e., assessing the construction process) (Alamargot et al., 2010). Unfortunately, most often only students' final products are evaluated. Process assessment has received far less attention in the research literature. The product-oriented perspective focusses on students' final summary products. In this respect, off-line data gathering can be conducted (i.e., after task execution) by means of trace analysis (Winne, 2010). More specifically, the quality of informative text traces and students' summaries' design and content can be evaluated by means of scoring rubrics (Merchie & Van Keer, 2014a). This trace analysis provides a retrospective picture of students' (regulation of) cognitive operations during summarizing (Boekaerts & Corno, 2005) (e.g., the correct application of generalization or deletion, engagement in pre-writing by structuring text information). Notwithstanding these traceable cognitive operations, important strategic actions are less visible afterwards, such as the time spent on pre-writing, ongoing construction or post-writing processes, or the way an order in which students elaborated their graphical summary. Capturing these process-oriented data on-line (i.e., during task execution) is more challenging, though very crucial, as it informs on the dynamic summarization process. Previous studies have already explored the use of digital pen technology for this kind of performance assessment (Alamargot et al,. 2010; van Hell, Kuks, Dekker, Borleffs, & Cohen-Schotanus, 2011). In previous research on graphical summarization (Merchie & Van Keer, 2014b), students were asked to schematize one text paragraph on special micro-dotted paper with a digital writing pen. Pen movements are registered and uploaded to the computer, resulting in 'pencasts', playable movies of the task execution process. The present study aims to go beyond, by investigating from both a product- and process-oriented perspective the evolution in graphically summarizing a multi-paragraph text after an instructional intervention.

Research aims

The first aim of this study is to investigate the impact of an instructional intervention including either researcher-provided or student-generated maps on students' evolution in (a) graphical summary products, i.e., the quality of the summary's design and content, (b) graphical summarization process, i.e., the duration of the summarization phases (i.e., pre-writing, construction, and post-writing). The second aim of this study is to provide an in-depth exploration of students' construction phase. More particularly, it is explored (a) whether different elaboration approaches and construction steps can be distinguished, (b) whether these are related to the quality of students' final products, and (c) whether these are related to the different instructional approaches in the intervention.

Method

Design

A quasi-experimental repeated measures design was applied to answer the research questions. Teachers were randomly assigned to either (1) a researcher-provided mind map condition, (2) a student-generated mind map condition and (3) a control condition. Experimental condition teachers were asked to implement a specific graphical summarization strategy instruction into their regular content courses for ten weeks, starting at the beginning of October 2011 until the end of December 2011. In September 2011 all experimental condition teachers received a training, outlining the aims of the project, and describing the instructional materials in detail. Control condition teachers were asked to follow their regular classroom curriculum and were not provided with any additional instructional materials. Three tests were administered, respectively at the beginning of October 2011, at the end of December 2011 and mid-March 2012 in students' regular classrooms.

Participants

A total of 18 students from 12 different classes were randomly selected from a larger scale study to complete an assignment with the digital writing pen. Respectively 5 researcher-provided mind map condition students, 8 student-generated condition students and 5 control condition students participated. There were 8 boys and 10 girls, 8 students from 5th grade and 10 students from 6th grade. Sixteen students were native Dutch speakers, which is the instructional language in Flanders. Two students had a different home language. Chi-square analyses indicated no significant differences in the distribution of gender (χ^2= 2.306, df= 2, p=.032), home language (χ^2=1.800 , df=2, p=.407), and grade (χ^2=0.686, df=2, p=0.710) across conditions.

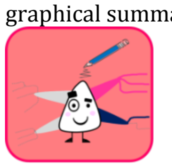
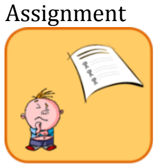
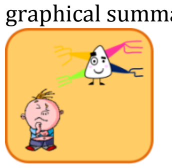
Intervention

A previously tested researcher-directed mind map training (Merchie & Van Keer, 2013) served as a baseline to elaborate on two different graphical summarization strategy instruction programs. Both programs (1) were theoretically based on the abovementioned conceptualization of an instruction in graphical summarization strategies and provide practice in the strategic activities implemented in the sequentially ordered phases of graphical summary construction (Table 1), (2) comprise ten lessons of fifty minutes each spread over ten consecutive weeks. Both programs differ greatly in their approach to stimulate the development of graphical summarization skills. In the first instructional approach, researcher-provided mind maps were used.

Here, instead of constructing graphical summaries themselves (step 3), students were asked complete specific assignments with the researcher-provided mind map (e.g., solving a crossword and indicating were they found the answer in the mind map). In the second instructional approach, student-generated mind maps were used as students' were gradually taught throughout the lessons to construct mind maps themselves (e.g., choosing relevant key words, hierarchically associating words, etc.) (Table 1).

Table 1

Correspondence between theoretical base and concrete strategic actions of the graphical summarization strategy instruction

			Conceptualization of strategic activities	
Theoretical base of the summarization process			RPMM condition	SGMM condition
Phases	Cognitive levels of processing	Mental operations	Strategic steps	Strategic steps
Pre-writing or planning phase	Micro-processing: micro-level representation (local coherence)	Repeated references Argument repetition	1. Scan and read the text  2. Find key words and structure 	Scan and read the text  2. Find key words and structure 
Construction phase	Macro-processing: Macro-level presentation (global coherence)	Deletion Generalization Construction	3. Mind map assignment 	3. Construct your graphical summary 
Post-writing or revision phase			4. Verify your Assignment 	4. Verify your graphical summary 

During the intervention, teachers were provided with all necessary instructional material, which consisted out of a student learning booklet with all color-print lessons, a teacher manual describing the lesson plans, objectives and assignment solutions, and a compilation reader with additional background information. To ensure fidelity to treatment, teachers were asked to complete a booklet with ten structured protocols, and fill in 1 protocol per lesson. These protocols indicated that the lessons were largely given as intended by the researchers. Furthermore, teachers were contacted during the intervention period by personal school visits, phone calls, and emails to question the teachers about the progress of the instructional program.

Instruments and procedure

A graphical summary task was administered. More particularly, students were asked to independently and graphically summarize an informative multi-paragraph text with the digital writing pen on a microdotted paper. Three 322-word informative texts were used respectively for the pretest (about the life of sea horses), posttest (about the life of meerkats), and retention test (about the life of hummingbirds). The texts contained three general text paragraphs (general information, body parts, and living environment) and were very comparable as to their technical reading and reading comprehension level. Possible comprehension problems were clarified by the researchers, however no students requested for any additional information. Students received specific instructions to correctly summarize with the digital writing pen. They were asked to press the circular 'record'-button on the operating panel, which was printed at the bottom of the page when starting the assignment. When finishing the assignment, they were asked to press the right-angled 'stop'-button on the operating panel. The task was executed in the near presence of the researcher. However, no instructions or hints were given on the construction of the GS.

Off-line data capturing

Informative text traces

Text traces were studied as they could provide an indication of students' strategic pre-writing actions. Traces in the informative texts were score on a 5-point scale as to the quality of the (sub)title markings, figure markings, use of different colors during highlighting and distinguishing main and sub-ideas by means of different colors (Merchie & Van Keer, 2014a). Interrater reliability coefficients (Hayes & Krippendorff, 2007), ranged from .81 to .97, indicating good to high interrater reliability.

Graphical design and graphical content

Graphical summary products were analytically scored by means of a previously developed mind map scoring rubric (MMSR) (Merchie & Van Keer, 2013). Various aspects of a good graphical summary were identified and scored on a 5-point scale. In the assessment of the graphical design, it is verified to which extent students followed specific design-principles: branch dimension, letter dimension, inclusion of images, readability, keyword place and radial structure. An overall mean score was calculated based on the score of these different sub-rubrics, representing the overall quality of the graphical summary's design (α_{pre}=.92 ,α_{post}=.94 ,

α_{ret}=.91). As working with the digital writing pen did not allow students to use any colors during the construction process, the sub-rubric 'color use' was left out of consideration. In the assessment of the graphical content, it is verified to which extent students' succeeded in graphically summarizing the text information. More particularly, the inclusion of arrows to visualize text relationships, the choice of relevant key words, content coverage, quality of the made associations, choice of blanket terms and degree of hierarchically elaborated main branches ('deepening'). An overall graphical content-score was calculated based on the scores of the sub-rubrics (α_{pre}=.96 ,α_{post}=.96 , α_{ret}=.95).

On-line data capturing

Writing period duration

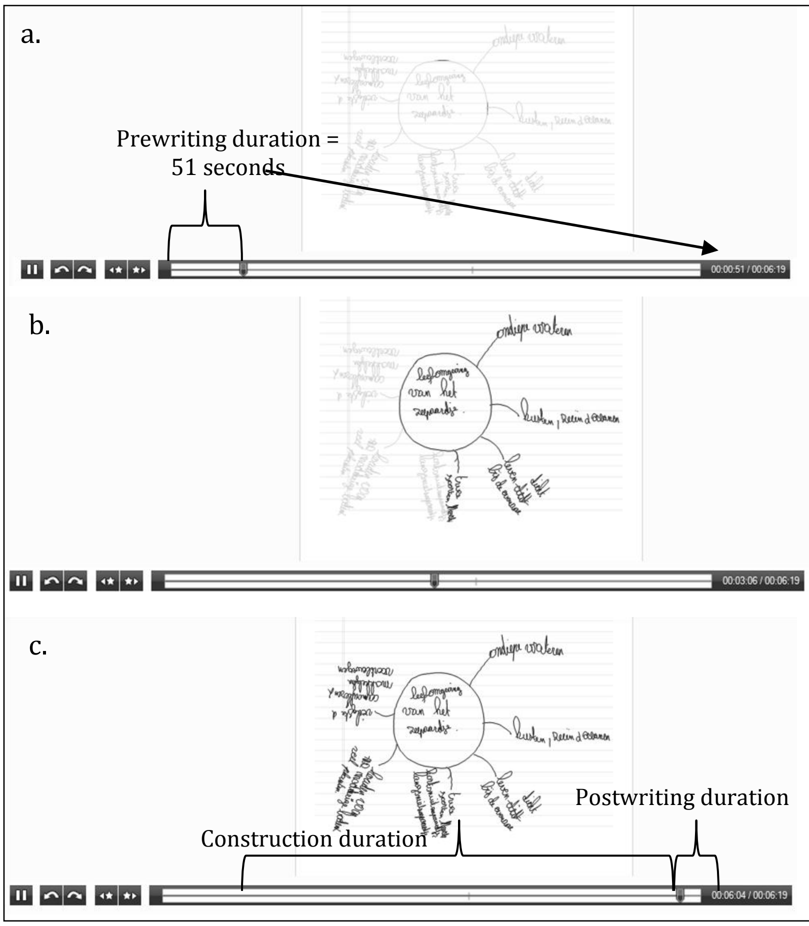
The duration of the writing periods was determined by analyzing the pencasts. Each pencast is complemented with a timeline, on which the exact duration of the writing periods can be verified (Figure 1). All pencasts were double coded by a second independent rater. Krippendorf's alpha (Hayes & Krippendorff, 2007) indicate good to excellent interrater reliability for the pre-writing (α_{pre}= .76, α_{post}= .69, α_{ret}= .81), construction (α_{pre}= .93, α_{post}= .99, α_{ret}= 1), and post-writing duration (α_{pre}= .89, α_{post}= .99, α_{ret}= .99).

Elaboration approaches

The construction process itself was also analyzed in detail. As to our knowledge, no specific literature documents on the analyses of the stepwise elaboration of graphical summaries, an inventory was made of all possible elaboration approaches. A first rater distinguished different elaboration approaches based on all the pencast data. These approaches were subsequently presented to a second rater, who independently rated each constructed summary according to the identified approaches. High to excellent interrater reliability coefficients (Hayes & Krippendorff, 2007) were established for pretest (α = .93), posttest (α=.99) and retention test (α=1).

Construction steps

In addition, it was explored whether different construction steps during graphical summary construction could be detected. A construction step is defined as the fluent association of key words and branches to each other. In this respect, a new construction step is started when the students for instance starts a new main branch (Figure 2). Similar to the procedure described above, construction steps were identified by a first rater. All graphical summaries were double coded, resulting in good to high interrater agreement ($\alpha_{pretest}$=.98, $\alpha_{posttest}$=.89, $\alpha_{retention\ test}$=.94).



The student presses 'record' and the writing pen starts recording pen movements. The total duration of the process here is 6 minutes and 19 seconds, which can be verified on the timeline. The pre-writing phase's duration is 51 seconds.

Hereafter, the student starts to construct the graphical summary. From this moment on the light grey text information turns black according to how the summary was gradually constructed by the student.

The construction phase stops when the student finishes the graphical summary. The post-writing phase starts when the student evaluates or revises the graphical summary. When the student finished the task, they were instructed to press the 'stop'-button.

Figure 1. Data capturing: Duration of the writing periods.

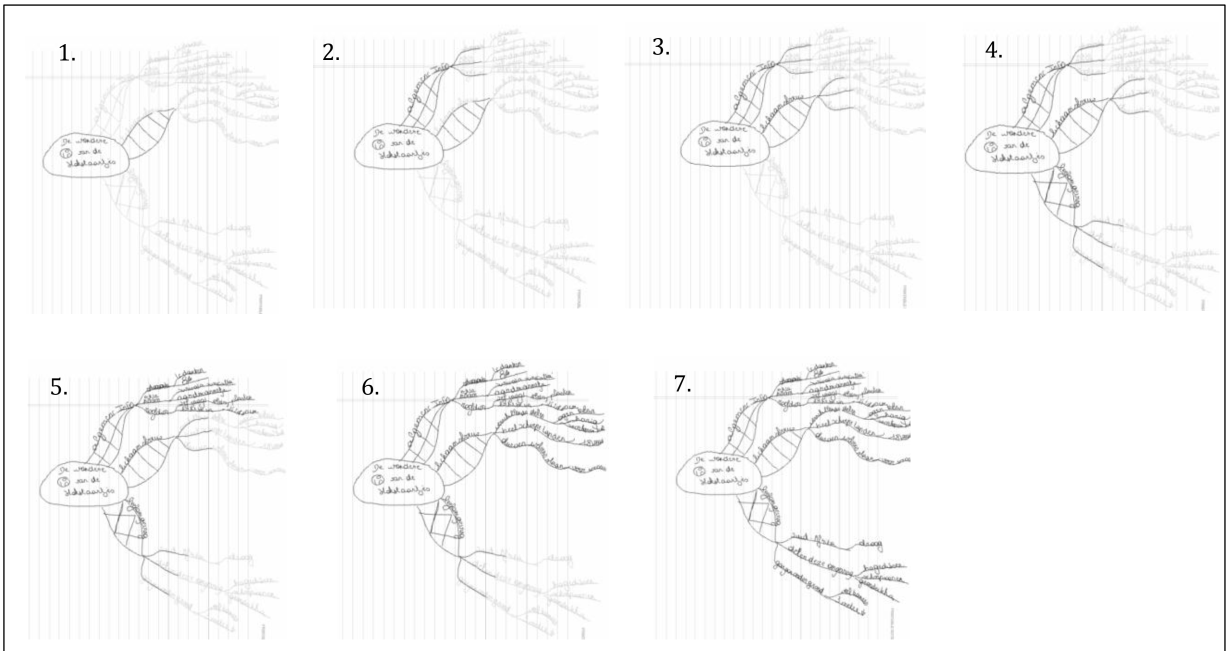


Figure 2. Illustration of the determination of the number of construction steps.

Data analysis

Students' product scores (i.e., scores on the informative text traces, scores on the sub-components of the graphical design- and content) and the duration of the writing periods were analyzed with a Repeated Measures Analysis of Variance. Greenhouse-Geisser-correction was applied as the data were non-spherical, probably due to the small sample size. Kruskal-Wallis one-way analyses of variance (Kruskal & Wallis, 1952), correlational and chi-square analysis were conducted to investigate the relationship between the elaboration approaches, construction steps, final product quality and different instructional approaches.

Results

The effects of different instructional approaches on students' graphical summarization

As to the product-assessment, no significant effects of time or interaction-effects between time and condition were found for the informative text traces (Table 2). Significant effects of time were found for all subcomponents of the graphical summary's design and content. Also several significant interaction effects are shown between time and condition (Table 2). In almost all cases, students from both experimental conditions obtain significant higher scores than control condition students, except for 'letter dimension', where only the student-generated experimental condition students differ significantly from the control condition students. Experimental conditions do not differ significantly among each other. As to the process-assessment, no significant difference over time is shown in pre-writing duration ($F(1.22, 18.34)=0.614$, $p=.475$), construction phase duration ($F(2, 13)=0.329$, $p=.725$), and post-writing duration ($F(1.30, 18.14)=0.636$, $p=.475$). Furthermore, no significant interaction effects were revealed between time and condition for duration of the pre-writing phase ($F(2.45,18.34)=1.469$, $p=.257$), the construction phase ($F(4, 26)=1.241$, $p=.318$), and the post-writing phase ($F(2.59,18.14)=0.305$, $p=.794$). Table 3 shows students' mean writing period duration across the different conditions for the three measurement moments.

In-depth exploration of the graphical summary construction process

Five main elaboration approaches could be distinguished (Figure 3). First, a linear sequential elaboration approach is followed when students copy key words or sentences linearly and no or very limited efforts are made to graphically link the information together. Second, students follow an inconsiderate elaboration approach when attempts are made to graphically represent the information, but this appears to happen rather thoughtlessly or illogically by freely associating key words to the center. There is a clear absence of hierarchically deepened elaborations. Third, a structured elaboration approach is followed when students first elaborate the structure of the summary (i.e., draw main and sub-branches) and subsequently position key words in this structure. Fourth, a main branch elaboration approach is followed when students first draw and define the main branches and then subsequently elaborate on them. This approach overlaps with the prescribed approach for constructing mind maps in more popular literature (Buzan, 2005; Hofman, 2011). Finally, students follow a successive branch elaboration approach when every text paragraph is subsequently and sequentially hierarchically elaborated. Figure 3 illustrates the stepwise elaboration of each approach. Further, the in-depth exploration revealed the possibility to identify the number of different graphical summary construction steps.

In a second step, it was investigated whether the different elaboration approaches and construction steps related to the quality of students' final products (i.e., graphical design-score and graphical content-score). Significant differences were found between the pretest-elaboration approaches and the graphical design- (χ^2= 13.448, df= 3, p=.004) and content scores (χ^2= 13.811, df= 3, p= .003) at pretest; between the posttest-elaboration approaches and the graphical design (χ^2= 10.679, df= 4, p=.030) and content scores (χ^2= 11.937, df= 4, p=.018) at posttest and between the retention test-elaboration approaches and the graphical design- (χ^2= 12.233, df= 2, p= .002) and content scores (χ^2= 12.202, df= 2, p=.002) at retention test. Additionally, correlations were calculated between the number of construction steps and the final product total-scores. No significant correlations were revealed between the number of pretest-construction steps and the graphical design (r=.448, p=.194) and content scores (r=.442, p=.201) at pretest; between the number of posttest-construction steps and the graphical design (r =-.244, p=.497) and content-scores (r=.066, p=.855) at posttest and between the number of retention test-construction steps and the graphical design, (r=.266, p=.457) and content-scores (r=.211, p=.559) at retention test.

In a third step, it was investigated whether the elaboration approaches and the number of construction steps can be related to the different instructional approaches of the different conditions. A chi-square analyses, using Fisher's exact test as the expected frequencies in each cell was less than 5 (Fisher, 1992), indicated no significant difference in the distribution of elaboration approaches across conditions (χ^2= 5.518, p=.661) at pretest. Most of the students followed a linear sequential elaboration approach. The distribution of elaboration approaches differs however significantly at posttest (χ^2= 18.800, p<.001) and retention test (χ^2= 15.934, p<.001). Whereas control condition students stick to the linear sequential approach, experimental condition students engage more in spatial text organization. Also most student-generated mind map condition students prefer a successive branch elaboration approach, even though they received practice in the main idea elaboration approach. As to the evolution in the number of construction steps, no significant evolution was found over time (F(2,14)=.819, p=.461) and no interaction effects were found between time and condition (F(4,28)=.300, p=.875).

Table 2

Results from the Repeated measures ANOVA on students' informative text traces and graphical summary products

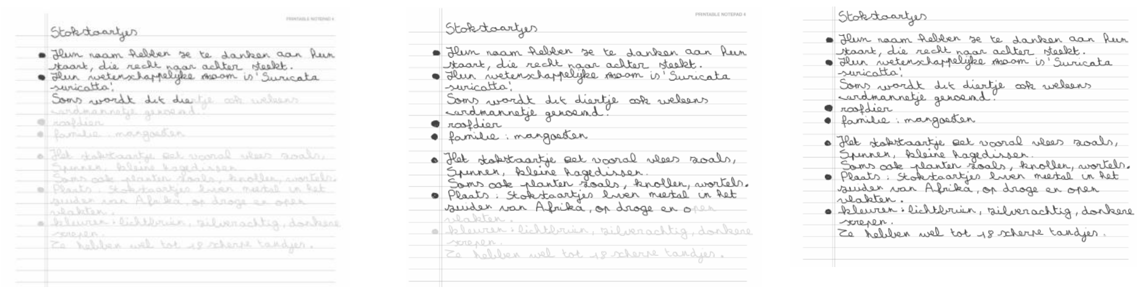
	Time		Time x Condition	
	F	*P*	*F*	*P*
Informative text traces				
Title markings	F(1, 15)=.510	0.486	F(2, 15)=.595	.564
Figure markings	F(1, 15)=.510	0.486	F(2,15)=.595	.564
Color use	F(2,14)=.261	.774	F(4,28)=.861	.499
Color main sub	F(2,14)=.261	.774	F(4,28)=.861	.499
Total score	F(1.34, 20.01)=.380	.605	F(2.68, 0.01)=.486	.675
Graphical summary product				
Graphical design				
Branch dimension	F(2,14)=17.335	< .001***	F(4,28)= 4.124	.009* *
Letter dimension	F(2,14)= 4.795	.026*	F(4,28)=3.330	.024*
Readability	F(1.24,18.65)=4.999	0.031*	F(2.49,18.65)=3.941	.030*
Keyword place	F(4,28)=6.515	< 0.001***	F(2,14)=27.673	.001**
Inclusion of symbols	F(2,14)=5.855	.014*	F(4,28)=3.210	.027*
Radial structure	F(1.24, 18.66)=5.766	.021*	F(2.49, 18.66)=4.444	.079
Total score	F(1.23, 18.44)=17.696	<0.001***	F(2.46, 18.44)=7.298	.003**
Graphical content				
Arrow inclusion	F(1.27, 18.99)=8.411	.006**	F(2.53,18.99)=5.170	.012*
Keyword choice	F(1.28, 19.18)=10.516	.003**	F(2.56,19.18)=5.026,	.012*
Content coverage	F(1.38, 20.70)=9.067	.004**	F(2.76,20.70)=3.575	.034*
Association	F(1.41, 21.15)=4.933	.027*	F(4.53,21.15)=2.929	.060
Blanket term choice	F(2, 14)=7.942	.005**	F(4, 28)=2.298	.084
Deepening	F(1.36, 20.38)=8.918	.004* *	F(2.72,20.38)=3.188	.050
Total score	F(1.28, 19.21)=10.477	.002**	F(2.56, 19.21)=4.458	.019*

Table 3

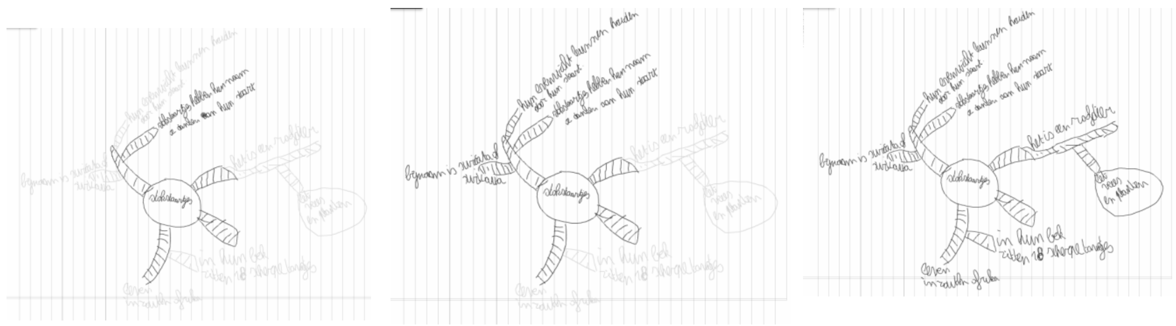
Mean duration of the writing periods (in seconds)

	Pre-writing M(SD)	Construction M(SD)	Post-writing M(SD)
Researcher-provided mind map condition			
Pretest	10.20(11.95)	672.60(188.36)	81.20(174.90)
Posttest	34.40(56.50)	844.20(209.17)	19.20(6.50)
Retention test	15.00(19.22)	631.40(130.33)	53.00(89.87)
Student-generated mind map condition			
Pretest	12.13(14.68)	720.25(310.91)	32.63(39.38)
Posttest	8.38(11.03)	688.13(283.34)	15.63(19.86)
Retention test	3.13(3.52)	741.75(354.23)	10.25(11.77)
Control condition			
Pretest	8.20(5.76)	814.50(511.35)	23.00(16.10)
Posttest	5.20(3.27)	637.75(54.73)	22.25(26.33)
Retention test	12.80(13.26)	640.75(338.50)	21.00(14.58)

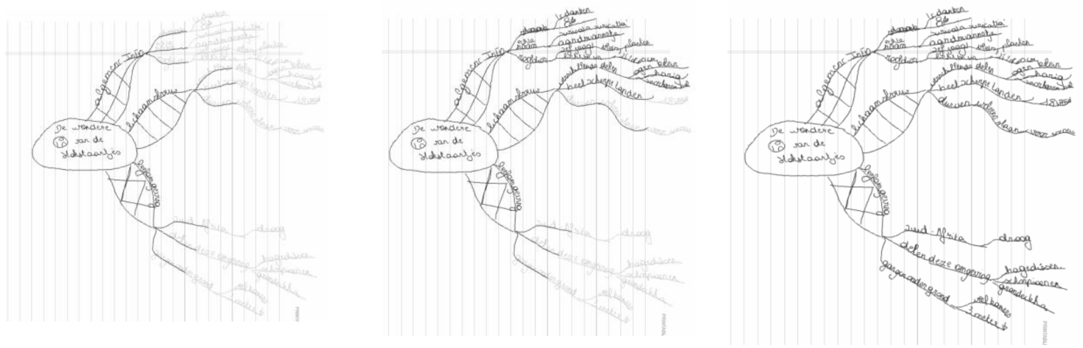
Linear sequential elaboration



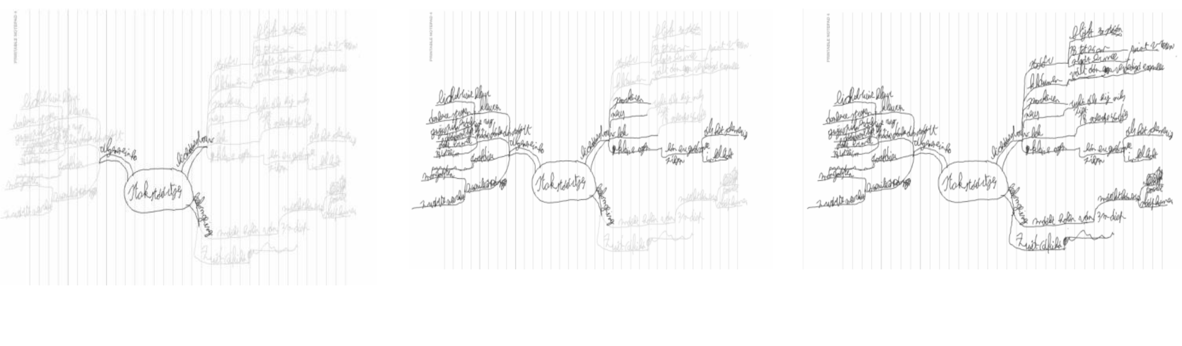
Inconsiderate elaboration



Structure elaboration



Main idea elaboration



Succesive branch elaboration

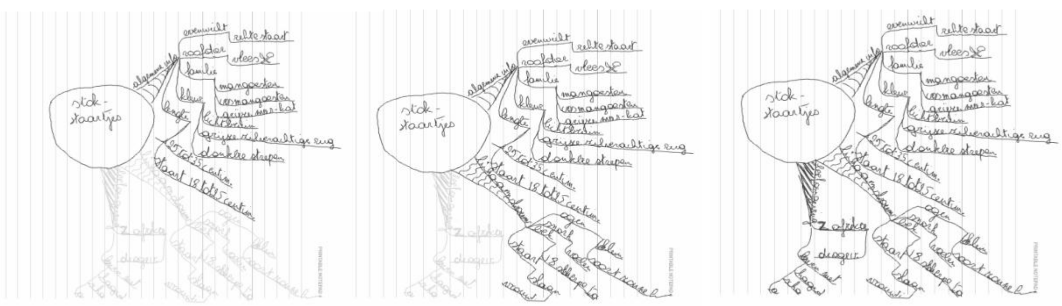


Figure 3. Overview of the different elaboration approaches.

Discussion

Discussion of the results

This study aimed to assess fifth- and sixth-grade students' evolution in graphical summarization skills in relationship with two different instructional approaches both from a product and process-oriented perspective. Two major lines of results are discussed. First, the analysis of both product- and process-oriented data, indicate that both experimental and control condition students, only limitedly engaged in profoundly preparing their graphical summary construction. Analysis showed no significant improvements in students' informative text traces and in the time spent on pre- and post-writing. Three different explanations might account for this finding. A first explanation is related to the development of students' cognitive writing processes. Late elementary students might still be limited in their capacity to use self-regulatory processes such as planning and revision, as their working memory is almost exclusively occupied with text production during the construction phase (McCutchen, Teske, & Bankston, 2008). Second, this study might not have fully acknowledged the cyclical nature of pre-writing, construction, and post-writing. These phases can be still tightly intertwined, especially in young children (Berninger et al., 1996; McCutchen, 2006) and thus not that easy to capture as three separate phases. Some strategic pre-writing actions (i.e., searching for repeated references) or post-writing actions (e.g., quickly reviewing) might thus have been embedded in the construction phase (Berninger et al., 1996). To verify this hypothesis, the defined construction steps were reviewed in-depth. This revealed some evidence for the existence of these on-line revision processes, as for example a particular student started a new construction step to complement the summary with earlier forgotten important key words. Rather surface-level on-line revision processes appear thus to already exist in the graphical summarization process of late elementary school children. Third, the little time spent on pre-writing could also be related to the level of prior knowledge students' already had from the text. Students were acquainted with the text topic, as it was already previously used in a study test. Therefore, students might had already formed some sort of micro-level representation of the text. Using less familiar texts in future research might reduce the possible influence of prior knowledge on students' duration of pre-writing.

A second line of results is related to the quality of students' final graphical summary products and the in-depth exploration of the construction phase. A significant improvements over time was found in the quality of both experimental condition students' final products. Experimental condition students seemed thus to have exceeded the more counterproductive copy-and-delete method by engaging more intensively in graphical text synthesis processes. This result supports previous studies (Merchie & Van Keer, 2013) and goes beyond as the construction phase was explicitly explored from a process-oriented perspective. This has, to our knowledge, seldom been investigated in the context of graphical summarization. Further, five different elaboration approaches were distinguished, which were shown to be related to the quality of students' final graphical summary products. It was possible to detect students following less effective approaches, such as the linear sequential, inconsiderate elaboration, and structured approach. By uncovering these less effective approaches, some important beginner difficulties in graphical summarization could be identified, such as difficulties with spatially reorganizing text, hierarchically deepen text ideas and adequately considering the text content. These difficulties are important to take into account when developing or adjusting strategy instruction (Hilbert & Renkl, 2008). Another noticeable result of this in-depth exploration was that experimental condition students, regardless whether they received explicit instruction in mind map construction or not, largely followed a successive branch elaboration approach. Although following this approach led to a good qualitative result, students still seem to rely heavily on the linear sequential text representation in elaborating their graphical summary. Probably, following this approach is well suitable at the beginning of a graphical summarization instruction to summarize relatively well-structured texts, as it resemblances most to linear fashion in which children spontaneously address informative texts. However, students could be drifted into difficulties when following this approach during graphically summarizing more ill-structured texts. Further research could corroborate these elaboration approaches and investigate them in relation to well- and ill-structured texts.

Limitations and implications

Four concrete limitations of this study must be are addressed in detail. First, process-oriented data was captured with the digital writing pen technology, which has shown to be a promising data gathering technique in previous research (Merchie & Van Keer, 2014b). Implementing this digital pen technology during a classroom assignment in this study was associated with some concerns. Despite the researcher's near presence and the clearly provided guidelines, students not always strictly respected these guidelines. This could be diverted from the audio recorded by the writing pen's in-built microphone. In future research it is therefore advisable to apply a strict protocol with guidelines when working with the writing pen, test students individually to avoid environmental distraction, or relate the pencasts to more sophisticate software systems, which automatically generate the duration of writing stages (Alamargot et al., 2010). A second concern relates to the interpretation of students post-writing strategic actions. For example, students can spent 10 seconds on post-writing but if the students makes no visible revisions, it is difficult to verify whether the students has reviewed his summary or they were just waiting to hand in their assignment. Therefore, future research should substantiate this data gathering technique with more objective data on students' strategic actions during pre- and post-writing, by means of retrospective interviews or eye-tracking (Alamargot et al., 2010). A third limitation is related to the small sample size of this study. which is partially due to some technical pencast errors. Therefore, some gathered data were excluded from the analysis. Fourth, future research could also investigate the relationship between graphical summarization and transcription skills (e.g., handwriting, spelling) (Berninger et al., 1996).

As to the implications for research, this study extends earlier work by including new possibilities for assessment by means of pencasts. In this respect, it must be considered as a first investigation in unraveling the development patterns in graphical summarization skills from both a product- and process-oriented perspective. Educational research is encouraged to fine-tune this form of assessment by the suggestions mentioned above. This study furthermore builds bridges between research and practice, by encouraging a joint assessment of students' graphical summarization product and ongoing process, as the proposed educational measurement technique can be easily applied by teachers. In contrast with expensive technology tools and software to analyze written products in educational research, this digital pen technology is more user-friendly for educational practitioners. When applying this technology in class, teachers will obtain a very detailed picture on students graphical summarization product (i.e., graphical design and content) and process (e.g., duration of the writing phases, elaboration approach, construction steps). This detailed picture can shape teachers' differentiated strategy instruction, facilitate feedback processes (van Hell et al., 2011) or can be used in individual training settings wherein students are coached in a one-on-one relationships. Furthermore, teachers can create dynamic worked-examples to provide it as a scaffold for their students.

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8 Mind mapping as a meta-learning strategy: Stimulating pre-adolescents' text-learning strategies and performance?

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Chapter 8
Mind mapping as a meta-learning strategy: Stimulating pre-adolescents' text-learning strategies and performance?

Abstract

This study examined the effectiveness of two instructional approaches of mind mapping used as a meta-learning strategy to stimulate fifth and sixth graders' text-learning strategies and recall performance. Thirty-five fifth- and sixth-grade teachers and 644 students from 17 different elementary schools participated. A randomized quasi-experimental repeated measures design was set up with two experimental conditions and one control condition. Students in the experimental conditions received a 10-week teacher-delivered instructional treatment, working with either researcher-provided or student-generated mind maps. Multilevel piecewise growth analysis was used to examine the evolution in students' cognitive and metacognitive text-learning strategies, and free recall performance. Results show the greatest gains from pre- to posttest and sustained effects from post- to retention test in observable cognitive text-learning strategy use for students in the condition with researcher-provided mind maps. These findings have direct implications for both research and practice. Challenges and facilitating factors for school-based intervention research are discussed.

Introduction

Effective strategies for text-based learning (i.e., processing, organizing, and acquiring knowledge from texts) are indispensable to manage the information glut in our 21st century (Alexander & Res 2012). These text-learning strategies become of particular importance in middle and high school where informative texts are increasingly used to reach instructional objectives and the expectations for independent text study increase substantially (Broer, Aarnoutse, Kieviet, & Van Leeuwe, 2002; Meneghetti, De Beni, & Cornoldi, 2007). Establishing a good study method by inducing and initiating a broad repertoire of text-learning strategies arises therefore as an important educational goal in late elementary grades (McNamara, Ozuru, Best, & O'Reilly, 2007). In this respect, students can strategically engage in a variety of observable and less-observable, deep- and surface level cognitive and metacognitive text-learning strategies during learning from text to support the essential cognitive processes of text selection, organization, transformation, and integration (Mayer, 2001; Schlag & Ploetzner, 2011).

To stimulate text-based learning, review studies have specifically illustrated the beneficial effects of well-planned and well-instructed use of graphic organizers or maps (e.g., Dexter &

Hughes 2011; Kim, Vaughn, Wanzek, & Wei, 2004; Nesbit & Adesope 2006; Vekiri, 2002). These two-dimensional spatial arrangements of words or word clusters (Stull & Mayer 2007) carry great potential as an organizational learning strategy (Dansereau & Simpson, 2009; Farrand, Hussain, & Hennessy, 2002; Vekiri, 2002), evoking active knowledge transformation which has shown to be related with deeper-level text processing and learning (Slotte & Lonka, 1999; Nesbit & Adesope, 2006). Moreover, some researchers also consider graphic organizers as a meta-learning strategy, helping learners to learn meaningfully and independently, inducing a larger strategy set (Chmielewski & Dansereau, 1998; Chiou, 2008).

Although the effects of various types of graphic organizers have already been extensively studied (e.g., concept maps; Novak, 2002; Chularut & DeBacker, 2004; Chiou, 2008), mind maps (Buzan, 1974; Buzan, 2005) have received far less empirical attention in contemporary educational intervention research. Disregarding the frequent use of mind maps in educational practice, their empirical investigation in late elementary grades is underaddressed in the current international research literature. Most published mind map research was executed in secondary or higher education and has focused on mathematics (Brinkmann, 2003), science (Abi-El-Mona & Adb-El-Khalick, 2010), or economics (Budd, 2004). The very limited number of mind map studies in elementary education have been mainly explorative by nature or focusing on teachers' views (Moi & Lian, 2007; Seyihoglu & Kartal, 2010). Further, only a limited number of these studies have appeared in high-quality indexed journals the past fifteen year. Consequently, studies empirically addressing mind map effects and their instructional use in elementary school-based intervention research are very scarce. The present study aims to bridge this gap by explicitly focusing on mind mapping used as a meta-learning strategy to initiate autonomous text-learning strategy use. Underneath, this aim is elaborated on from a theoretical and empirical perspective. First, the definition and effectiveness of graphic organizers, such as mind maps, are described and it is clarified how mind mapping can be considered as a meta-learning strategy. Second, we specifically focus on how mind mapping can help students in their independent text processing and learning. Next, after conceptualizing a mind map strategy instruction, two instructional mind map approaches are discussed.

Mind mapping and meta-learning

A mind map (MM) (Buzan, 1974, 2005) is a particular type of a higher-level graphic organizer, transforming linear text into a graphical representation (Figure 1). As other types of graphic organizers (e.g., concept maps, knowledge maps), they are typified as follows: (a) they contain words or word groups, (b) the spatial arrangement between these elements indicate text relations, and (c) they represent the conceptual organization of a text (Stull & Mayer, 2007). In a mind map, the linear text content is reorganized by placing the text's central theme in the middle of the page, from which several related main text ideas radiate out in the shape of colorful thick branches. Associated to these main branches, other smaller sub-branches represent subordinate text ideas. In this way, a mind map reflects the macro structure of the text together with more precise relationships among related text units. Mind maps furthermore allow the representations of more complex text relationships (e.g., contrasts, causations, comparisons) by adding numbers, images, arrows, or connectors to the branches (Buzan, 2005). The specific mind map characteristics (e.g., radial structure, use of visual imagery, gestalt principles), supported by educational and brain research (e.g., Anderson & Hidde, 1971; Budd, 2004; Haber, 1970; O'Donnell, Dansereau, & Hall, 2002), make mind maps significantly different from traditional temporarily ordered linear summaries. They also diverge from similar types of graphic organizers such as concept maps, which are hierarchically top-down oriented, rely less on specific design-principles (e.g., using colors or images), and require the explicit use of connective terms between concepts (Budd, 2004; Davies, 2011).

Children's rights can be grouped into three main categories. The first group of rights, provision rights, deals with rights that provide facilities to survive and develop. Examples of these rights are having the right to adequate food, to go to school, to health care, and to recreation. The second group of rights, protection rights, protects children from abuse, exploitation, and neglect (e.g., protection against children labor, the right to special care). Participation rights are a third group of rights, providing children the opportunity to participate in society, e.g., the right on an own opinion and right to information.

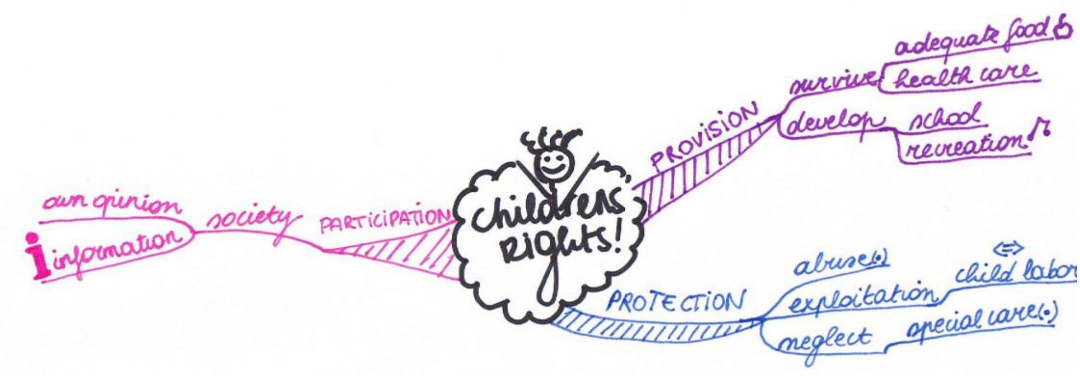

Figure 1. Informative text paragraph and its graphical transformation into a mind map.

Theoretically, the Dual Coding Theory (Paivio, 1991) and the Conjoint Retention Hypothesis (Kulhavy, Stock, Peterson, Pridemore, & Klein, 1992; Robinson, Robinson, & Katayama, 1999; Robinson & Molina, 2002) underpin the use of working with graphic organizers or maps. Both theories, extensively discussed by Vekiri (2002) and Nesbit and Adesope (2006), emphasize the importance of conjointly encoding information both non-verbally or spatially and verbally. By the interconnectedness of the verbal and visual system, associative connections can be made and learning is facilitated. Empirically, various meta-analyses, covering more than hundred studies, consistently confirm the effectiveness of mapping as an organizational learning strategy, helping students to learn (e.g., Dexter & Hughes, 2011; Nesbit & Adesope, 2006; Vekiri, 2002). Also mind mapping was already studied in higher education as an organizational strategy to schematically represent information (Zipp, Maher, & D' Antoni, 2009) or as a prompted study technique (Farrand et al., 2002). However, some researchers go beyond considering mind mapping as an organizational strategy and point at the potential of mapping methods for meta-learning (Chmielewski & Dansereau, 1998; Chiou, 2008; Okebukola, 1992). This term was originally introduced in educational research by Biggs (1985) and further elaborated by Jackson (2004), referring to a strategy helping students learn how to learn meaningfully and independently. Chmielewski and Dansereau (1998), for instance, found a positive transfer of text processing skills after having trained university students in using and constructing maps, even when the mapping was not explicitly applied during learning. Also Chiou (2008) refers to concept mapping as a 'meta-learning strategy', empowering students 'learning how to learn'. Despite this potential, very few studies have investigated mapping as a means for meta-learning and no researchers specifically addressed the value of mind mapping as a meta-learning strategy in elementary education. The present study therefore aims to renew the interest on this topic and fill the gap in the current mind map research literature by thoroughly investigating how mind mapping can be used to induce a larger text-learning strategy repertoire during independent text learning.

Using mind mapping as a meta-learning strategy to support learning from text

A wide range of text-learning strategies, (e.g., highlighting, note taking, rereading), have been reported in the literature to stimulate the essential processes of text selection, organization, and transformation, leading to text integration into long-term memory (Mayer, 1996; Mayer, 2001; Schlag & Ploetzner, 2011). These processes respectively refer to the selection of relevant words, the organization of this selected information into coherent mental representations, and transformation processes to generate a verbal and pictorial mental model which is integrated into long-term memory (Mayer, 2001). Students can engage in a variety of text-learning strategies, which can been categorized according to their nature (e.g., cognitive and metacognitive strategies) (Weinstein, Jung, & Acee, 2011), level of depth (e.g., surface-level versus deep-level strategies) (Lahtinen, Lonka, & Lindblom-Ylänne, 1997), or perceptibility (e.g., overt observable strategies or covert non-observable strategies) (Kardash & Amlund, 1991). Previous research on pre-adolescents' text-learning strategy use indeed identified in this respect various overt and covert cognitive (e.g., summarizing, highlighting, paraphrasing) and metacognitive text-learning strategies (e.g., planful approach, monitoring, and self-evaluation) (Merchie, Van Keer, & Vandevelde, 2014; Merchie & Van Keer, 2014). Effective learning from texts requires the application of these text-learning strategies in a self-regulated, strategic, and goal-oriented way (Mayer, 2001; Schlag & Ploetzner, 2011; Wade, Trathen, & Schraw, 1990). However, recent findings show rather inefficient and superficial text-learning strategy use in pre-adolescence (Merchie et al., 2014; Merchie & Van Keer, 2014) and researchers call for longitudinal interventions inducing a large and flexible repertoire of diverse strategies (Donker, de Boer, Kostons, Dignath van Ewijk, & van der Werf, 2014; Simpson & Nits, 2000, Weinstein et al., 2011). Implementing mind mapping as a meta-learning strategy seems promising to this end because of various reasons.

First, working with mind maps might prompt cognitive strategy use during learning from text. When working with mind maps, students are deliberately involved in reorganizing text information by cognitively searching for and interpreting associations among concepts in the text (Brinkmann, 2003; Davies, 2011; Farrand et al., 2002). By means of this cognitive search, students receive practice in important cognitive text-learning strategies such as organization (e.g., highlighting important information), elaboration (e.g., paraphrasing, making links with prior knowledge, and relating text to pictures), and rehearsal (e.g., rereading, reviewing notes) (Weinstein et al., 2011; Weinstein & Mayer, 1986). The study of Broer et al. (2002) indicated in this respect, that a lesson series in making schematic representations positively influenced sixth graders' spontaneous application of this strategy during autonomous study. Second, working with mind maps can also trigger metacognitive engagement during learning from text (Hilbert & Renkl, 2008; Nesbit & Adesope, 2006). Hilbert and Renkl (2008) refer, in this respect, explicitly to the metacognitive function of mapping, by becoming aware of comprehension problems during explicating or constructing maps. To induce metacognitive engagement (i.e., planning, monitoring, and evaluation), metacognitive prompts such as checklists or lesson reviews can be included, helping learners to implement a systematic regulatory sequence controlling their performance (Askell-Williams, Lawson, & Skrzypiec, 2012; Schraw 1998). To date however, very little research documents on the transfer of taught metacognitive strategies to independent text-learning. Third, the induced text-learning strategies by means of the mapping training might be transferred to independent learning tasks, affecting students' text recall (Chmielewski & Dansereau, 1998). Unfortunately, students' retention of text information has been mainly studied after being explicitly prompted to use maps as a learning tool (e.g., Chularut & DeBacker, 2004; Nesbit & Adesope, 2006). However, there are indications that mapping training can increase the recall of text ideas even without explicitly applying the mapping strategy (Chmielewski & Danserau, 1998), and that the use of maps results in a positive transfer in learning situations were no maps are available (Schnotz, 2002).

Conceptualizing a mind map strategy instruction

As mentioned above, the research literature points at the potential of mind mapping as a meta-learning strategy, helping students 'learn how to learn'. Therefore, a mind mapping strategy instruction was conceptualized in the present study (Table 1), to induce specific cognitive (i.e., organization, elaboration, and rehearsal) (Weinstein et al., 2011) and metacognitive strategies (i.e., planning, monitoring, and evaluation) (Schraw, 1998), as both cognitive and metacognitive strategies should be the focus of instruction when stimulating strategic learning (Simpson & Nist, 2000). These strategies were linked to the essential processes during learning from text on the one hand (i.e., text selection, organization, transformation, and integration) (Mayer, 2001; Schlag & Ploetzner, 2011) and specific learning techniques (e.g., scanning the text, highlighting) on the other hand (Askell-Williams et al., 2012; Schlag & Ploetzner, 2011). As to the latter, students are stimulated to get a general overview of the to-be-learned text material in a first step of the strategy instruction. This step focuses on incorporating specific reading and comprehension activities, such as scanning text, reading and clarifying difficult words or text parts during reading (De Corte, Verschaffel, & Van De Ven, 2001; Zimmerman, Bonner, & Kovach, 2002). These learning techniques touch upon the metacognitive strategy 'planning' (Schraw, 1998), including for example orientation to the text. In a second and third step, students select and organize important information by means of highlighting, and information transformation is encouraged by the use of mind maps. The focus here lies on organization, elaboration, and rehearsal strategies (cognitive strategy use; Weinstein et al., 2011) and on monitoring text comprehension and processing (metacognitive strategy use; Schraw, 1998). Finally, in a fourth step, students are encouraged to review the process followed and evaluate their outcomes (metacognitive strategy use; Schraw, 1998).

Table 1
Conceptualization of the mind map strategy instruction of the present study

Induced (meta)cognitive text-learning strategies (Weinstein et al., 2011; Schraw, 1998)	**Essential cognitive processes during learning from text** (Mayer, 2001, Schlag & Ploetzner, 2011)	**Sequentially ordered learning techniques** (Askell-Williams et al,. 2012; Schlag & Ploetzner, 2011)
Planning	Text selection	Getting an overview: Scan and read the text Clarify incomprehension
Organization Elaboration Rehearsal Monitoring	Text organization	Identifying key information: Highlight relevant key words
	Text transformation	Working with mind maps
Evaluation	Text integration	Process and product evaluation

Two instructional mind map approaches

A rich history of studies supports the conclusion that interventions with longer-term and more complex instruction are required to teach students how to learn and that essential strategies for text-based learning can be taught through a variety of well-planned instructional techniques from late elementary grades on (Dignath, Buettner, & Langfeldt, 2008; Merchie & Van Keer, 2013; Mok, Ma, Liu, & So, 2005; Wolters, Benzon, & Arroyo-Giner, 2011). In this respect, it is essential to identify the most effective instructional approach for integrating mind mapping as a meta-learning strategy into domain-specific content courses wherein students are provided with opportunities to apply and practice the newly acquired text-learning strategies (Dignath et al., 2008).

With regard to this instructional approach, a well-known discussion is going on about working with researcher-provided versus student-generated maps (Kirschner, Sweller, & Clark, 2006; Lee & Nelson, 2005; Stull & Mayer, 2007). On the one hand, researchers are pleading for working with student-generated maps based upon the activity theory, which states that deep learning involves the engagement of learners in productive learning activities (Kirschner et al., 2006; Stull & Mayer, 2007). In this respect, generative processing (i.e., deeper cognitive processing of the material) is induced by 'learning by doing', challenging learners to think deeply and letting them actively engage in selecting and organizing text in relation to their existing knowledge structures (Kirschner et al., 2006; Stull & Mayer, 2007). However, learners' generative processes might also be inhibited by the extra cognitive demands this active engagement entails (Stull & Mayer, 2007). On the other hand, researchers mainly inspired by cognitive load research (Sweller & Chandler, 1994) support the use of author- or researcher-provided maps. By providing students with worked-examples and letting them 'learn by viewing', the level of extraneous processing is reduced. More cognitive capacity is available for generative processing, inducing learners to seek understanding of how the linear text is selected, organized, and transformed into a spatial structure. Texts complemented with worked-examples of maps would thus provide more opportunities to learn, as they offer a scaffold for students' strategic processing (Kirschner et al., 2006; Leopold, Sumfleth, & Leutner, 2013; Stull & Mayer, 2007).

To our knowledge, there is hardly any research on the influence of these instructional approaches on elementary students' spontaneous unprompted strategy use, since previous research has largely focused on the performance of secondary and higher education students' learning with either provided or self-constructed maps (e.g., Stull & Mayer, 2007; Leopold et al., 2013). Hence, this raises the important question of which instructional approach best promotes strategy transfer. In this respect, research on strategy transfer and the promotion of self-regulated learning seems to favor a learning by doing-approach, indicating that strategy transfer is more likely to occur when (a) learners are treated as active participants (Garner 1990), and (b) direct promotion of strategies is provided by explicit instruction in specific strategy components (Frazier, 1993, Kirstner et al., 2010).

The current study

Above, we argued that working with mind maps might support students' autonomous text-based learning. More particularly, we expect that implementing mind mapping as a meta-learning strategy will induce students' cognitive and metacognitive text-learning strategy use and increase their recall performance during independent text-learning. Additionally, it is hypothesized that when students learn by doing, more spontaneous text-learning strategy application will occur. Hence, it is expected that greater gains in text-learning strategy use and recall performance will be found for students working with student-generated maps. The present research investigates the following research questions:

1. What is the impact of two instructional approaches of mind mapping (i.e., with researcher-provided and student-generated mind maps) on pre-adolescents' spontaneously applied cognitive and metacognitive strategy use?

2. What is the impact of two instructional approaches of mind mapping (i.e., with researcher-provided and student-generated mind maps) on pre-adolescents' free recall performance?

Method

Design

A quasi-experimental repeated measures design (i.e., pretest, posttest, retention test) was applied. Elementary schools who agreed to participate in the study were randomly assigned to either (a) a condition with researcher-provided mind maps (RPMM), (b) a condition with student-generated mind maps (SGMM), or (c) a control condition. To avoid design contamination effects, teachers within the same school were assigned to the same condition. Teachers in the experimental conditions embedded a specific teacher-directed instructional approach of mind mapping once a week over a 10-week interval in their social study and science lessons during regular classroom hours. Classes assigned to the control condition received no explicit strategy instruction in text-learning strategies and teachers followed their usual teaching repertoire. Control classes were provided with the opportunity to use the instructional material during the subsequent school year. The conducted research consisted of five phases: (1) pretest administration (midterm September 2011); (2) a focused 1.5 hour after-school training for teachers in the experimental conditions (midterm September 2011); (3) ten-week intervention period (from October until midterm December 2011); (4) posttest administration (midterm December 2011); and (5) retention test administration (midterm March 2012). Figure 2 illustrates the design of the study.

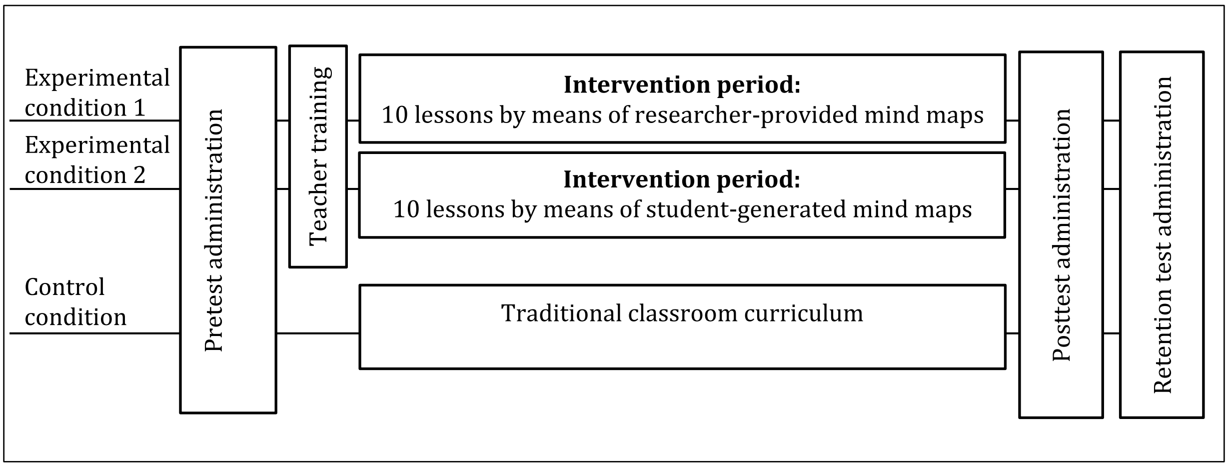

Figure 2. Design of the study.

Participants

Fourteen fifth-grade teachers, fifteen sixth-grade, and six multigrade teachers and their 644 students from 17 different elementary middle-class schools from the same socio-economic area in Flanders (the Flemish-speaking part of Belgium) participated in the study. Multigrade teachers in the present study are teaching multigrade classes comprising students from fifth and sixth grade, which retain however their grade-specific designation and textbooks (Mulryan-Kyne 2007). The average class size was approximately 19 students (*SD*=4.68) per class. Teachers were on average 34.74 years old (*SD*=9.49) and had on average 13.77 years (*SD*=9.21) of teaching experience. Eight teachers were men (22.9%). Table 2 presents the characteristics of the teachers in all conditions. Chi-square analyses indicated no significant differences in the distribution of gender (χ^2=0.413 *df* =2, *p*=.205) and grade (χ^2=0.694, *df* =4, *p*=.311) across conditions. Furthermore, one-way analysis of variances indicated no significant differences between the three conditions regarding teachers' age (*F*(2,34)=0.134, *p*=.875) and teaching experience (*F*(2,34)=0.265, *p*=.769).

Students average age was 11.44 (*SD*=0.68), with 53.9% boys and 46.1% girls in the sample. The majority of the students had Dutch, which is the instructional language in Flanders, as their home language (94.5%). Table 3 summarizes students' characteristics (gender, home language, and grade) in the three research conditions. Chi-square analyses indicated no significant differences in the distribution of home language (χ^2=5.004, *df* =2, *p*=.082) and grade (χ^2=7.552, *df* =2, *p*=.023) between the three conditions. However, a significant difference in distribution was found according to gender (χ^2=7.552, *df* =2, *p*=.023), as the control condition included more boys. From all parents passive informed consent was obtained as they were offered the opportunity to withdraw their child from participation in the study.

Table 2
Teacher characteristics

	Researcher-provided mind map condition		Student-generated mind map condition		Control group	
	N	%	*N*	%	*N*	%
Gender						
Male	2	14.3	2	20	4	36.4
Female	12	85.7	8	80	7	63.6
Total	14	100	10	100	11	100
Grade						
Fifth grade	5	35.7	4	40	5	45.5
Sixth grade	5	35.7	5	50	5	45.5
Multigrade	4	28.6	1	10	1	9
Age	*M*	*SD*	*M*	*SD*	*M*	*SD*
	35.14	8.25	35.20	11.56	37.00	9.75
Years of teaching experience	*M*	*SD*	*M*	*SD*	*M*	*SD*
	12.79	8.33	13.30	10.17	15.45	10.04

Table 3

Student characteristics

	Researcher-provided mind map condition		Student-generated mind map condition		Control group	
	N	%	*N*	%	*N*	%
Gender						
Male	108	50.9	108	49.3	131	61.5
Female	104	49.1	111	50.7	82	38.5
Total	212	100	219	100	213	100
Home language						
Dutch	191	91.8	209	96.8	200	94.8
Other language	17	8.2	7	3.2	11	5.2
Total	208	100	216	100	211	100
Grade						
Fifth grade	95	44.8	92	42.0	106	49.8
Sixth grade	117	55.2	127	58.0	107	50.2
Total	212	100	219	100	213	100

Intervention

General features of the mind map strategy instructions

A previously tested mind map training (Merchie & Van Keer, 2013) was used as the basis for the development of two strategy instruction programs. Both programs include 10 lessons of 50 minutes each, spread over 10 consecutive weeks, and share a general structure. In the first lesson, students were introduced to essential mind map characteristics (e.g., radial structure, color use, dimension). Lesson 2 to 9 were devoted to the gradual instruction, practice, and application of specific text-learning strategies, supporting the essential text-learning processes, by means of four sequentially ordered learning techniques, i.e., (1) scanning the text, reading the text and clarifying incomprehension ('getting an overview'), (2) identifying key information by highlighting relevant key words, subideas, and supporting details in different colors ('text organization'-strategy), (3) active manipulation of the text material by means of mind map assignments ('text transformation'-strategy), and (4) reviewing the process and product outcomes (cf., Table 1). This strategy instruction can be regarded as a multicomponent instruction (Edmonds et al., 2009), as the intervention included instruction in various text-learning strategies. The tenth and final lesson was spent on explicitly addressing the transfer of mind mapping in multiple content areas (e.g., writing, mathematics, French).

Informative texts used in both experimental conditions were identical and derived from students' grade-specific social studies and science textbooks. Texts were provided for fifth and sixth grade, addressing their grade-specific subject-matter on nature (e.g., animals in fifth grade, ecology in sixth grade), history (e.g., World War I in fifth grade and armistice in sixth grade), and society (e.g., the town council in fifth grade and country's governance in sixth grade). As lessons progressed, structural clues and signaling devices in the informative texts (e.g., subheadings, words printed in italics or boldface indicating or emphasizing text structure) (Lorch, 1989) were gradually omitted, to induce students' independent selection and organization processes. On the basis of prior research (Merchie & Van Keer, 2013) and elementary school teachers' suggestions, these texts were previously evaluated and adjusted as to their length, difficulty, clarity, content, and organization.

Experimental conditions were provided with all necessary teaching materials to implement the lessons, i.e., learning books for the students with all color-print lessons and teacher manuals. These manuals comprised the ten detailed lesson plans with lesson objectives and assignment solutions, classroom posters, and a compilation reader with additional background information.

Two distinct instructional approaches

Regardless of the identical included grade-specific informative texts, and similar implementation structure of the first, second, and fourth learning technique, experimental conditions differ significantly in the implementation of the third learning technique, that is the active manipulation of text material by means of mind mapping. As to the first instructional approach, which was implemented in experimental condition 1, researcher-provided mind maps (RPMM) were applied. Mind maps included into the lessons were previously evaluated (Merchie & Van Keer, 2013) and drawn by hand by a researcher trained in mind mapping. Paper-and-pencil mind maps were deliberately used as this was most similar to students' paper and pencil assignments. After scanning, reading, and structuring the text, various text-learning strategies (i.e., organization, elaboration, rehearsal, monitoring) are induced through different types of exercises students had to complete on the basis of the texts and the accompanying researcher-provided mind map example. To this aim, teachers used techniques to induce strategic learning (Simpson & Nist 2000). For example, students searched for particular answers in the mind map by means of elaborative interrogation (i.e., asking why-questions to connect their prior knowledge with informative text information) and applied the mind map to search for and deliberately draw inferences, create and track analogies or contrasts, and explicitly explain relationships between concepts in mind map and text. In the teacher training and manual teachers were requested to predominantly apply modeling and guided practice, and to ensure explicit feedback on each completed exercise. Further, the manual provided elaborated suggestions to incorporate individual work, group work, and discussions in the lessons as well.

As to the second instructional approach, which was implemented in experimental condition 2, student-generated mind maps (SGMM) were used for initiating text-learning strategy use, evoking the explicit application of text-learning strategies (i.e., organization, elaboration, rehearsal and monitoring) by gradually teaching students to construct mind maps themselves. In this way strategic learning was induced by letting students search for main and sub-branches themselves, and asking them to deliberately include arrows and figures into the mind map to portray important text inferences and relationships (e.g., analogies, contrasts). By means of the teacher manuals teachers were requested to teach students directly how to construct mind maps. Here also, elaborated suggestions were incorporated to use individual work, group work and discussions. Appendix A provides an example lesson showing the four main phases of each lesson and the differences between both instructional approaches.

Teacher training

One week before the intervention and after pretest administration, all experimental schools were visited individually, providing fifth- and sixth-grade teachers with a researcher-directed 1.5 hour after-school training. At the beginning of the training each teacher was provided with a grade-specific teacher manual for lesson preparation and consultancy reference when delivering instruction (100 pages), and with a compilation reader with background information on the use of mind maps (125 pages). The training consisted of the following parts: (1) a detailed description of the rationale of the study, (2) the demonstration and exemplification of the specific mind map characteristics and the use of mind mapping as a meta-learning strategy, and (3) a thorough presentation of the instructional materials, including an overview of the phases, topics, structured activities, classroom assignments, and suggested instructional strategies per lesson.

Ensuring fidelity to treatment

Three main methods were applied to assure and enhance treatment fidelity (O'Donnell, 2008; Smith, Daunic, & Taylor, 2007; Swanson, Wanzek, Haring, Ciullo, & McCulley, 2013). First, teachers were asked to complete a structured protocol booklet during the intervention period (1 protocol per lesson, consisting of three main sections). Herein, teachers indicated the specific date and hour of the taught lesson, together with the total time spent on each lesson. Further, teachers evaluated per lesson on a 5-point Likert-scale to which degree (a) each lesson objective, which reflected critical intervention components and were stated in teachers' manuals, was attained, (b) each assigned activity was completed, and (c) the instructional materials for both teachers and students were clear. Two open questions concluded the protocol, asking for teachers' additional remarks or suggestions. Second, teachers' lessons implementation and protocol completion was encouraged by three-weekly phone calls and personalized electronic reminders. Schools were given the opportunity to subscribe to an additional school visit in case of additional questions or instructional difficulties. Third, after the ten-week intervention, teachers received an additional questionnaire. This questionnaire queried which particular instructional strategies were applied per lesson (e.g., whole-class instruction, group work, individual work). Further, teachers were asked to answer on a 5-point Likert-scale various items related to (a) students' attitude during the lessons (e.g., Were students motivated during the lessons?), (b) teachers' experiences during the project (e.g., Was it difficult for you to integrate mind mapping?), (c) the instructional material (e.g., Was the material attractive?), and (d) the achievement of the main lesson objectives (e.g., Is the majority of the students capable of making specific mind map assignments?). Also interview information was collected as background information to help interpret the protocols and questionnaire information. In this way, treatment fidelity measures were collected both qualitatively and quantitatively.

Dependent measures

Overview of the task administration

At pretest, posttest, and retention test, a list of tasks was administered to elicit students' spontaneous (meta)cognitive text-learning strategy use during independent text learning and to evaluate their recall performance. First, before the onset of the learning task, a prior knowledge test was administrated, asking students to write everything down what they already knew about the topic of the text, as this might influence students' text processing and learning (Armand, 2001; Ausubel, 1968). These student notes were matched to the information reflected in the text content. The percentage of text information that was already covered in the notes was applied as the measure of students' prior knowledge. It was found that students had very limited or no prior knowledge about the text topics during the three measurement moments ($M_{pretest}$=2.03; $SD_{pretest}$=1.78; $M_{posttest}$=0.99; $SD_{posttest}$=1.39; $M_{retention\ test}$=0.66; $SD_{retention\ test}$=1.59). Second, after prior knowledge test completion, the learning task was administered. Students were instructed to study a 500-word informative text to prepare for a test afterwards without any prompted strategy use (Veenman 2011). They received a finite amount of study time (30 minutes) to elicit efficient regulation of study activities (Leopold & Leutner, 2012; Rawson & Dunlosky, 2007). For the three measurement occasions, three different informative texts were used, respectively about the life of seahorses (pretest), meerkats (posttest), and hummingbirds (retention test). The same texts were used for fifth and sixth grade. All texts were comparably subdivided into six text paragraphs accompanied by the following subheadings: general information, body parts, living environment, eating habits, reproduction, and interesting facts. The first four paragraphs were complemented with a picture. During the learning task, students were allowed, but not obligated to use scratch paper. Third, students were requested to answer a task-specific self-report inventory concerning their applied text-learning strategies. Fourth, students were asked on a free recall test to write everything down they still remembered from the text.

Cognitive and metacognitive text-learning strategy use

As advised in the literature, students' overt and covert cognitive and metacognitive text-learning strategy use was measured by combining task-specific self-reports with detailed trace analysis of the informative texts and the scratch papers (Samuelstuen & Braten 2007; Scott, 2008; Winne, 2010).

Self-reported text-learning strategy use

To gain insight into students' text-learning strategy use, the task-specific self-report Text-Learning Strategies Inventory (TLSI) was administered (Merchie et al., 2014) immediately after completion of the learning task. The TLSI comprises nine subscales: summarizing and schematizing (7 items, α_{pre}=.89, α_{post}=.90, α_{ret}=.91), highlighting (1 item), rereading (3 items, α_{pre}=.74, α_{post}=.80, α_{ret}=.77), paraphrasing (7 items, α_{pre}=.76, α_{post}=.82, α_{ret}=.82), linking with prior knowledge (3 items, α_{pre}=.74, α_{post}=.80, α_{ret}=.78), studying titles and pictures (3 items, α_{pre}=.61, α_{post}=.69, α_{ret}=.71), planful approach (3 items, α_{pre}=.65, α_{post}=.69, α_{ret}=.74), monitoring (5 items, α_{pre}=.70, α_{post}=.71, α_{ret}=.71), and self-evaluation (5 items, α_{pre}=.72, α_{post}=.71, α_{ret}=.75). Good model fit results were obtained for this nine-factor model in a confirmatory factor analysis (YB χ^2= 1014.708, *df*= 588, *p* <.001, CFI= .93, TLI= . 92, RMSEA= .03 with a 90% CI [.03, .04], SRM = .05) (Merchie et al., 2014). Table 4 presents some example items of the subscales. Students were asked to complete the self-report questionnaire on a 5-point Likert scale, indicating to which degree they applied the strategies during the abovementioned learning task activity (Braten & Stromso, 2011; Leopold & Leutner, 2012). Subscale scores for pretest, posttest, and retention test were calculated in SPSS 18.

Table 4

Example items of the Text-Learning Strategies Inventory-subscales (Merchie et al., 2014)

	N_{items}	Example item
Summarizing and schematizing	7	*I repeated the text with my summary or graphic organizer on my scratch paper*
Highlighting	1	*I marked the most important things*
Rereading	3	*To learn the text, I read the text a lot of times*
Paraphrasing	7	*I covered up the text information and tried to recall it*
Linking with prior knowledge	3	*Before learning, I thought about what I already knew*
Studying titles and pictures	3	*I looked at the titles to understand the text*
Planful approaching	3	*First, I read the whole text and then I started learning*
Monitoring	5	*While learning, I checked what I had already done and how much I still had to do*
Self-evaluation	5	*I managed to learn the text in a good way*

Observed text-learning strategy use

Informative texts and scratch papers were collected for investigating overt observable strategy use on students' study material by means of trace methodology (Braten & Samuelstuen, 2007; Winne, 2010). Traces were examined in detail by a trained team of three researchers by means of a previously developed scoring rubric (Appendix B), allowing to study both the quantity and quality of the text or scratch paper notes (e.g., Braten & Samuelstuen, 2007; Meier, Rich, & Cady, 2006; Nitko & Brookhart, 2007). First, informative texts traces (IT traces) were scored on a 4-point scale as to the following seven categories: (sub)title markings, figure markings, marking sentences or key words into the paragraph information, quantity of the marked information, used color quantity, color use for distinguishing between main and subideas, and manner of color use. Based on these scores, an overall mean score was calculated, representing the overall quality of text selection and organization on the informative text (7 items, α_{pre}=.80; α_{post} =.82; α_{ret} =.80). This score was transformed to a score on 10.

Second, for the trace analyses on the scratch paper (SP traces) different components of a good graphical summary were coded on a 4-point scale (e.g., Merchie & Van Keer, 2013; Hilbert & Renkl, 2008; Lee & Nelson, 2005; Taricani & Clariana, 2006), i.e., the hierarchical structure of the written information, the degree of hierarchy, color use, the integration of key words, and content coverage. Similar to the IT trace-score, a mean score was calculated representing the overall quality of text transformation on the scratch paper (5 items, α_{pre}=.89; α_{post} =.91; α_{ret} =.91) and transformed to a score on 10. Study materials from 225 students (35%) (78 RPMM condition students, 74 SGMM condition students, and 75 control condition students) were double coded for the three measurement occasions to check interrater reliability by means of Krippendorff's alpha (Hayes & Krippendorff, 2007). Table 5 presents the Krippendorff's alpha (α) interrater reliability coefficients of the coded trace categories. Krippendorff's alpha ranged from .81 to .99, indicating good to excellent agreement.

Table 5
Overview of the Krippendorff's alpha interrater reliability coefficients for the scored traces on informative text and scratch paper

Informative text traces		α_{pre}	α_{post}	α_{ret}
(Sub)title markings		.96	.94	.94
Figure markings		.95	.94	.92
Distinguishing main and sub-ideas	paragraph markings	.95	.93	.81
Quantity of markings	paragraph markings	.97	.96	.94
Color quantity	color use	.99	.99	.99
Distinguishing main and sub ideas	color use	.99	.98	.99
Manner of color use	color use	.99	.98	.98
Overall IT trace score		.99	.99	.98
Scratch paper traces		α_{pre}	α_{post}	α_{ret}
Structure	hierarchy	.98	.96	.96
Degree	hierarchy	.96	.99	.98
Color use		.95	.97	.99
Integrating key words		.97	.97	.97
Content coverage		.98	.95	.98
Overall SP trace score		.99	.98	.99

Recall performance

To measure students' text recall, a free recall test was administered after completion of the TLSI. Students were asked to write everything down they remembered from the text. Students' free recall was compared with the text content and a free recall score was calculated, representing the percentage of correctly recalled text information (McNamara & Kintsch, 1996).

Data analysis

To investigate the short-term (posttest) and relatively longer term (retention test) effects of both instructional mind map programs on students' text-learning strategy use and free recall performance, multilevel piecewise growth analyses was performed in MLwiN 2.25 as the data under investigation have a clear hierarchical three-level structure. More particularly, measurement occasions (i.e., pre-, post-, and retention test) (level 1) are clustered within students (level 2), which are in turn nested within classes (level 3). In this respect, the interdependency between students, as belonging to the same class and sharing a common history and experiences, was explicitly taken into account (Maas & Hox, 2005). Multigrade classes were included as one class into the analyses, as fifth- and sixth-grade students share the same teacher. In view of the analysis, the time span from pretest to retention test is split up into a first piece (P_1) covering students' evolution from pretest to posttest, and a second piece (P_2) covering students' evolution from posttest to retention test.

For each of the dependent variables (i.e., the nine subscale-scores on the TLSI, fourteen trace-scores and free recall score), three main steps were taken into the analyses. In the first step of the analysis, a three-level conceptual null model was estimated (model 0), which served as a baseline to compare with more complex models. This model predicts the overall pretest score on the dependent variable and the overall change from pretest to posttest (P_1 = phase 1) and from posttest to retention test (P_2 = phase 2) for all students across all classes. In a second step, the experimental conditions were included into the model to investigate the differential scores of the experimental groups contrasted against the control group (model 1). In a third step, interaction effects were included between condition and P_1 and P_2 to investigate the differential progress of the experimental groups contrasted against the control group (model 2). By means of chi-squared tests it was tested whether the individual parameters in the model are significantly different from zero.

Results

Pre-analysis: Assessment of treatment fidelity

First, analysis of the structured protocols showed that teachers in both experimental conditions implemented the mind map-lessons in a consistent way and at the requested frequency of one lesson per week. Average time spent on each lesson ranged from 45 to 70 minutes, without significant differences between the experimental conditions (p=.116). In both experimental conditions the main objectives and the assigned activities per lesson were indicated as largely or fully attained and completed for the vast majority of the lessons. Instructional teacher and student materials were found to be clear.

Second, three schools, (i.e., two RPMM condition schools and one SGMM condition school) requested a school visit and were individually visited by the researcher.

Third, corresponding to the lesson specifications in the teachers' manuals, both conditions reported to have mainly used whole-class instruction and modeling during the first lessons and applied more varied instructional strategies as the lesson series progressed (e.g., individual and group work). Further analysis of the teacher questionnaires indicated that (a) students were motivated (M_{RPMM}= 4.30, SD_{RPMM}=.48; M_{SGMM}= 4, SD_{SGMM}=.53, p=.188) and concentrated (M_{RPMM}= 4.15, SD_{RPMM}=.38; M_{SGMM}= 4.12, SD_{SGMM}=.35, p=.863) during the lessons, (b) teachers did not find it difficult to implement the lessons (M_{RPMM}= 2.23, SD_{RPMM}=.93; M_{SGMM}= 2.75, SD_{SGMM}=.89, p=.221) and believed that the instructional program had helped them to implement text-learning strategies into their regular school curriculum (M_{RPMM}= 4.23, SD_{RPMM}=.44; M_{SGMM}= 4.25, SD_{SGMM}=.46, p=.925). Furthermore they (c) underlined the attractiveness of the lesson material (M_{RPMM}= 4.61, SD_{RPMM}=.51; M_{SGMM}= 4.50, SD_{SGMM}=.53, p=.625) and reported that (d) they had largely attained the main lesson objectives (M_{RPMM}= 3.56, SD_{RPMM}=.42; M_{SGMM}= 3.83, SD_{SGMM}=.25, p=.117).

Evolution in self-reported and observed cognitive and metacognitive text-learning strategy use

A first aim of this study was to investigate whether the mind mapping intervention programs can be beneficial for students' independent cognitive and metacognitive text-learning strategy use. Results from the self-reported and observed strategy use analyses are represented successively.

Self-reported strategy use

First, the results of the evolution in self-reported text-learning strategy use are presented, which allow us to gain more insight into the overtly and covertly used text-learning strategies. Table 7 more particularly summarizes the model 2 estimates for the three-level analyses of the nine subscale scores of the TLSI. The intercept β_0 in the first column represents the mean pretest score for all students in all control condition classes. The parameters for the RPMM and SGMM condition in the column representing the pretest scores are differential with respect to the control condition and consequently must be added to or subtracted from the control condition pretest score to obtain the mean pretest score for all students in all classes in respectively the RPMM and SGMM condition. In the phase 1 column, the mean increase or decrease from pre- to posttest is shown for all students in all classes for the three different conditions. These parameters, also differential with respect to the control condition, must be added or subtracted from students' pretest score to obtain the mean posttest score for the students in respectively the RPMM, SGMM, and control condition. In the phase 2 column, the mean increase or decrease from post- to retention test is shown for all students in all classes for the three different conditions. To obtain the mean retention test score, these parameters must be added or subtracted to students' mean posttest score to obtain the mean retention test score in respectively the RPMM, SGMM, and control condition. In the last column, the variances at the different levels are represented, based on the conceptual null models, showing for each separate subscale the total variance partitioned into the between-classes variance (level 3), between-students within-classes variance (level 2) and between-measurements within-students variance (level 1). As to the first four subscales (i.e., 'summarizing and schematizing', 'highlighting', 'rereading', and 'paraphrasing') variances on each of the three levels were significantly different from zero. For the other five subscales (i.e., 'linking with prior knowledge', 'studying titles and pictures', 'planful approach', 'monitoring', and 'self-efficacy') only the variance at level 2 and 1 was significantly different from zero, indicating that the total variance of those dependent variables can be explained by differences between students and measurement occasions.

As to phase 1, four main findings draw our attention. First, students from both experimental conditions reported significantly less paraphrasing-activities during learning from text (i.e., covering texts parts and trying to recall, mentally retelling text information) (χ^2_{RPMM} = 15.031, *df* = 1, *p* <.001; χ^2_{SGMM} = 19.820, *df* = 1, *p* <.001) as opposed to the control condition, reporting significantly more use from pretest to posttest (χ^2 = 8.546, *df* = 1, *p* = .003). Second, students from the control condition reported significantly more summarizing and schematizing activities (i.e., using scratch paper for learning) (χ^2 = 11.298, *df* = 1, *p* <.001), but engaged significantly less in linking prior knowledge (i.e., before learning, thinking about what they already know about the topic) (χ^2 = 16.779, *df* = 1, *p* <.001). Third, students from the SGMM-condition have a significantly lower score on 'self-evaluation' directly after the intervention period (χ^2_{SGMM} = 5.803, *df* = 1, *p* = .016) and consequently seemed to be less self-assured about their text-learning approach. Fourth, when comparing both experimental conditions in phase 1, no significant differences could be observed.

As to phase 2, regarding the evolution from posttest to retention test, no significant evolution or devolution was found on reported text-learning strategy use for students in the RPMM condition when contrasted with students from the control condition. SGMM condition students, however, reported significantly less rereading-activities (χ^2_{SGMM} = 4.062, *df* = 1, *p* = .044), linking with prior knowledge-activities (χ^2_{SGMM} = 4.601, *df* = 1, *p* = .031), studying titles and pictures-activities (χ^2_{SGMM} = 7.473, *df* = 1, *p* = .006), monitoring (χ^2_{SGMM} = 8.375, *df* = 1, *p* = .004), and self-evaluation activities (χ^2_{SGMM} = 5.240, *df* = 1, *p* = .022) than the control group. As to the paraphrasing-activities, control condition students' subscale scores significantly declined during phase 2 (χ^2 = 4.631, *df* = 1, *p* = .034). Further, when comparing experimental condition students with each other, RPMM condition students outperform SGMM condition students in phase 2 on rereading (χ^2=4.303, *df* = 1, *p*=0.038), monitoring (χ^2= 13.094, *df* = 1, *p* < .001), and self-evaluation strategies (χ^2=10.634, *df* = 1, *p* = .001). RPMM condition students more particularly reporting a significantly higher use of these strategies.

Observed strategy use

The findings regarding self-reported strategy use must be complemented with results from the overt text-learning strategy analysis, stemming from students' observable text-noting behavior on their informative text and scratch paper. When first inspecting the level variances (Table 7, 8), variances on each of the three levels for all dependent variables were significantly different from zero.

With regard to the analyses of the traces on the informative text (Table 8), students from both experimental conditions evolve significantly more than students from the control condition in phase 1 on almost every coded informative text-noting behavior. This is also reflected into the overall informative text score, which reflects the overall quality of text selection and organization on the informative text (χ^2_{RPMM} = 38.792, df = 1, p <.001; χ^2_{SGMM} = 21.969, df = 1, p <.001). Students from both experimental conditions marked significantly more titles, subtitles, and key sentences, or words in the paragraph information and differentiated more between main and subideas in the text by means of different colors. When mutually comparing experimental condition students' informative text traces, RPMM condition students outperform SGMM condition students in phase 1 on the amount of applied colors in the informative text (χ^2=8.211, df = 1, p = .004). Figure 3 illustrates the difference between a highlighted text paragraph of a RPMM condition student, a SGMM condition student, and a control condition student, receiving the highest overall posttest informative text scores.


De wondere wereld van het stokstaartje

Algemene informatie

Stokstaartjes zijn bijzondere diertjes. Hun naam hebben ze te danken aan hun staart, die recht naar achter steekt. Zo blijven ze in evenwicht als ze recht staan. Hun wetenschappelijke naam is 'suricata suricatta'. Soms wordt dit diertje ook weleens aardmannetje genoemd.

Het stokstaartje is een roofdier omdat hij vooral vlees eet en zelf jaagt op voedsel. Hij behoort tot de familie van de mangoesten. Hieronder behoren onder andere ook de vosmangoest en de grijze meerkat. Stokstaartjes hebben een lichtbruine kleur, een grijze zilverachtige rug en donkere strepen. Ze worden ongeveer 25 tot 35 centimeter lang, met een staart van 18 tot 25 centimeter!

<u>RPMM-condition student</u>

- Marking of (sub)titles by means of two different colors (cf., color quantity, subtitles markings).
- Key words or key sentences are highlighted within the paragraph information (cf., distinguishing main and sub ideas).
- Two other different colors indicate the distinction between main and sub ideas into the paragraph. Into the right corner, the student has specified the color hierarchy (cf., color quantity, distinguishing by color use, manner of color use).


De wondere wereld van het stokstaartje

Algemene informatie

Stokstaartjes zijn bijzondere diertjes. Hun naam hebben ze te danken aan hun staart, die recht naar achter steekt. Zo blijven ze in evenwicht als ze recht staan. Hun wetenschappelijke naam is 'suricata suricatta'. Soms wordt dit diertje ook weleens aardmannetje genoemd.

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<u>SGMM-condition student</u>

- Marking of titles and subtitles in one color (cf., color quantity, subtitles markings).
- Key words are underlined within the paragraph information (cf., distinguishing main and sub ideas).
- Text highlights are used to mark the correspondence between picture and text information. Underlining in a different color indicates important main and sub ideas in the paragraph (cf., color quantity, distinguishing by color use, manner of color use).


De wondere wereld van het stokstaartje

Algemene informatie

Stokstaartjes zijn bijzondere diertjes. Hun naam hebben ze te danken aan hun staart, die recht naar achter steekt. Zo blijven ze in evenwicht als ze recht staan. Hun wetenschappelijke naam is 'suricata suricatta'. Soms wordt dit diertje ook weleens aardmannetje genoemd.

Het stokstaartje is een roofdier omdat hij vooral vlees eet en zelf jaagt op voedsel. Hij behoort tot de familie van de mangoesten. Hieronder behoren onder andere ook de vosmangoest en de grijze meerkat. Stokstaartjes hebben een lichtbruine kleur, een grijze zilverachtige rug en donkere strepen. Ze worden ongeveer 25 tot 35 centimeter lang, met een staart van 18 tot 25 centimeter!

<u>Control condition student</u>

- Marking of titles and subtitles in various colors without clear meaning (cf., color quantity, subtitles markings).
- Large or whole text parts are highlighted (cf., distinguishing main and sub ideas).
- Three different colors are used in the paragraph, combining different manners of color use (cf., color quantity, distinguishing by color use, manner of color use).

Figure 3. Overt text-learning strategy use in the informative text at posttest.
Note. For more information on the coded trace categories, see Appendix B.

As to phase 2, students in the SGMM condition show a significant decline with regard to title (χ^2_{SGMM} = 14.094, df = 1, p < .001) and paragraph markings (χ^2_{SGMM} = 5.915, df = 1, p = .015), whereas RPMM condition students evolve significantly more in marking figure information (χ^2_{RPMM} = 5.729, df = 1, p = .017) when contrasted with control condition students. Further, RPMM condition students outperform SGMM condition students on subtitle (χ^2=5.060, df = 1, p = .024) and figure markings (χ^2=6.566, df = 1, p = .010).

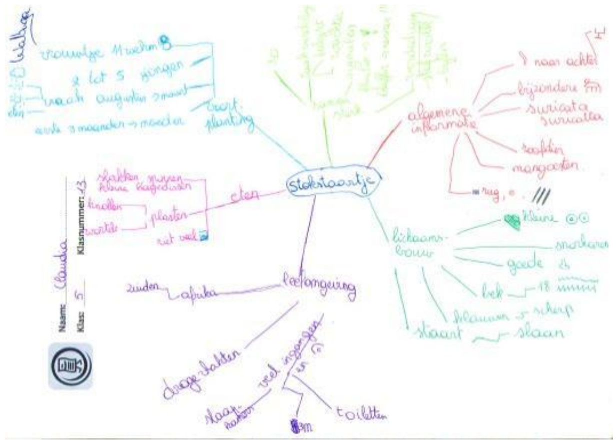
With regard to the traces on students' scratch papers, a detailed examination of Table 9 reveals various significant findings which should be interpreted carefully. Even though students from the control condition significantly engaged in more scratch paper use from pre- to posttest, students from both experimental conditions engaged significantly more in active knowledge transformation when compared with the control condition students. Analyses show in this respect the greatest gains for RPMM condition students, who significantly evolve on almost every coded category. RPMM condition students even outperform SGMM condition students in phase 1 on hierarchical degree (χ^2=7.433, df = 1, p = .006), color use (χ^2=4.001, df = 1, p = . 045), integration of key words (χ^2=4.239, df = 1, p = .039), and the overall scratch paper score (χ^2=6.221, df = 1, p = .013). Although control condition students reached higher scratch paper scores as well (χ^2 = 10.648, df = 1, p = .001), they mostly focused on linearly copying numerous key words, whereas experimental condition students reached higher levels of knowledge transformation by including a more hierarchical structure (χ^2_{RPMM} = 14.013, df = 1, p <.001; χ^2_{SGMM} = 3.944, df = 1, p =.047) and more hierarchical relationships (χ^2_{RPMM} = 40.361, df = 1, p <.001; χ^2_{SGMM} = 13.578, df = 1, p <.001). Figure 4 illustrates the difference in scratch paper use between students from the three conditions, receiving the highest overall posttest scratch paper-scores.

As to phase 2, this degree of hierarchy (χ^2_{RPMM} = 6.536, df = 1, p = .011) declines significantly for students in the RPMM condition. However, their positive evolution in phase 1 sustained three months after the intervention period in contrast with the SGMM condition scores, which decline significantly in phase 2 for almost every coded category. Table 6 provides a descriptive overview of the number of students applying highlighting and using scratch paper on the different measurement moments.

Table 6

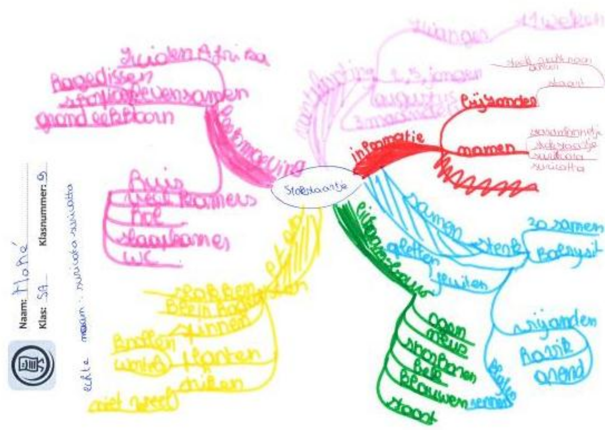
Numbers of students using highlighting and using scratch paper during pretest, posttest and retention test

	RPMM condition	SGMM condition	Control
Informative text			
Pretest	176	194	192
Posttest	201	196	192
Retention test	203	199	200
Scratch paper			
Pretest	104	109	109
Posttest	146	130	128
Retention test	137	98	132



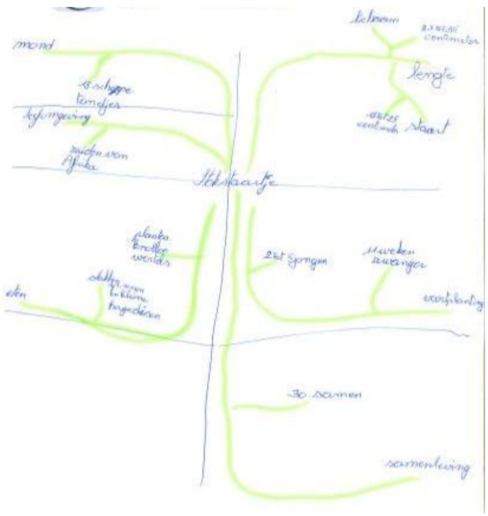
RPMM-condition student

- Graphical, radially structured
  (cf., hierarchical structure and degree)
- Integration of different colors
  (cf., color use)
- Incorporation of key words
  (cf., integrating key words)
- Different paragraph information included
  (cf., content coverage)



SGMM-condition student

- Graphical, radially structured
  (cf., hierarchical structure and degree)
- Integration of different colors
  (cf., color use)
- Incorporation of key words
  (cf., integrating key words)
- Different paragraph information included
  (cf., content coverage)



Control condition student

- Graphical, radially but unstructured
  (cf., hierarchical structure and degree)
- Integration of different colors for summary structure and content
  (cf., color use)
- Incorporation of key words
  (cf., integrating key words)
- Different paragraph information included, although less detailed
  (cf., content coverage)

Figure 4. Overt text-learning strategy use on the scratch paper at posttest.
Note. For more information on the coded trace categories, see Appendix B.

Evolution in free recall performance

As to the evolution in free text recall (Table 10), students from the control condition evolve significantly more in phase 1 (χ^2 = 40.508, df = 1, p <.001), whereas students from the SGMM condition have significantly lower scores (χ^2 = 7.948, df = 1, p =.004). As to phase 2, no significant changes in free recall score occur for the three conditions.

Table 7

Summary of the Model 2 estimates[a] for the three-level analysis of the Text-Learning Strategies Inventory subscales[b] for the three conditions[c]

	Pretest score			**Phase 1 (Evolution from pre- to posttest)**			**Phase 2 (Evolution from posttest to retention test)**			**Proportion of the variance at the three levels[d]**	
	RPMM condition	**SGMM condition**	**Control condition Intercept β_0**	**RPMM condition**	**SGMM condition**	**Reference Category: Control condition**	**RPMM condition**	**SGMM condition**	**Reference Category: Control condition**		
SS	+0.065 (0.199)	-0.030 (0.210)	2.711 (0.146)	+0.015(0.127)	-0.182(0.125)	+0.299(0.089)*	-0.020(0.126)	-0.237(0.125)	-0.081(0.089)	3 2 1	11.79%* 34.13%* 54.08%*
HL	-0.131 (0.128)	-0.105 (0.131)	4.476 (0.092)	+0.122(0.131)	-0.049(0.130)	+0.012(0.092)	-0.036(0.131)	-0.178(0.130)	+0.108(0.093)	3 2 1	2.84%* 25.65%* 71.51%*
RR	-0.077 (0.138)	+0.095 (0.143)	3.335 (0.100)	-0.167(0.112)	-0.156(0.112)	-0.122(0.079)	+0.007(0.113)	-0.255(0.112)*	-0.005(0.080)	3 2 1	5.02%* 38.88%* 56.10%*
PAR	+0.060 (0.104)	+0.051 (0.107)	3.063 (0.075)	-0.339(0.087)*	-0.386(0.087)*	+0.180(0.062)*	+0.100(0.087)	+0.052(0.086)	-0.133(0.062)*	3 2 1	3.35%* 47.58%* 49.07%*
LPK	-0.076 (0.129)	-0.201 (0.131)	3.496 (0.092)	+0.107(0.129)	+0.116(0.128)	-0.371(0.091)*	-0.182(0.129)	-0.273(0.127)*	-0.140(0.091)	3 2 1	2.57% 33.36%* 64.07%*
TP	+0.104 (0.108)	+0.048 (0.109)	3.474 (0.076)	-0.062(0.104)	+0.004(0.102)	-0.08(0.073)	-0.122(0.104)	-0.280(0.103)*	+0.088(0.073)	3 2 1	1.41% 42.83%* 55.76%*
PA	+0.212 (0.126)	+0.181 (0.129)	3.663 (0.090)	-0.250(0.135)	-0.252(0.133)	-0.113(0.095)	+0.137(0.135)	+0.001(0.133)	-0.127(0.095)	3 2 1	1.87% 25.47%* 72.66%*
MON	+0.233* (0.099)	+0.137 (0.100)	3.029 (0.070)	-0.082(0.088)	-0.039(0.087)	-0.035(0.062)	+0.062(0.088)	-0.251(0.087)*	-0.077(0.062)	3 2 1	2.62% 50.36%* 47.38%*
SE	-0.066 (0.069)	-0.005 (0.071)	4.130 (0.049)	-0.090(0.063)	-0.151(0.063)*	+0.068(0.045)	+0.060(0.063)	-0.143(0.062)*	+0.050(0.045)	3 2 1	2.90% 43.01%* 54.09%*

Note. [a] Significant parameters are indicated with an asterisk (*), standard error estimates are placed between brackets; [b] SS= summarizing and schematizing, HL= highlighting, PAR= paraphrasing, LPK= linking with prior knowledge, TP= studying titles and pictures, PA= planful approach, MON= monitoring, SE= self-efficacy; [c] RPMM-condition= researcher-provided mind map condition, SGMM-condition= student-generated mind map condition; [d] 3= class-level variance, 2 = student-level variance, 3 = measurement occasion-level variance in the fully unconditional three-level null models.

Table 8

Summary of the Model 2 estimates[a] for the three-level analysis of the traces on the informative texts[b] for the three conditions[c]

	Pretest score			Phase 1 (Evolution from pre- to posttest)			Phase 2 (Evolution from posttest to retention test)			Proportion of the variance at the three levels[d]	
	RPMM condition	SGMM condition	Control condition Intercept β_0	RPMM condition	SGMM condition	Reference Category: Control condition	RPMM condition	SGMM condition	Reference Category: Control condition		
(Sub) title markings	-0.201 (0.272)	+0.085 (0.289)	0.971 (0.201)	+0.927 (0.160*)	+0.916 (0.158)*	-0.070 (0.113)	-0.238 (0.160)	-0.594 (0.158)*	+0.131 (0.113)	3 2 1	17.55%* 20.79%* 61.66%*
Figure Markings	-0.070 (0.079)	+0.010 (0.082)	0.444 (0.058)	-0.027 (0.068)	+0.033 (0.067)	+0.016 (0.048)	+0.163 (0.068)*	-0.010 (0.067)	-0.065 (0.048)	3 2 1	5.10%* 30.38%* 64.52%*
Disting. Main/sub ideas	-0.059 (0.122)	+0.154 (0.128)	1.468 (0.089)	+0.368 (0.097)*	+0.181 (0.096)	+0.088 (0.068)	-0.143 (0.097)	-0.233 (0.096)*	-0.069 (0.069)	3 2 1	7.82%* 26.01%* 66.17%*
Quantity Highlight. text	-0.236 (0.196)	-0.019 (0.206)	2.111 (0.143)	+0.642 (0.134)*	+0.262 (0.132)*	+0.239 (0.094)*	-0.132 (0.134)	-0.211 (0.132)	+0.091 (0.094)	3 2 1	9.90%* 30.48%* 59.62%*
Color quantity	-0.102 (0.159)	-0.139 (0.167)	1.353 (0.116)	+0.390 (0.122)*	+0.377 (0.121)*	+0.089 (0.086)	-0.009 (0.122)	-0.182 (0.121)	-0.014 (0.086)	3 2 1	8.53%* 22.13%* 69.34%*
Dinsting. main/sub ideas (by color)	-0.140 (0.122)	-0.091 (0.128)	1.223 (0.089)	+0.450 (0.095)*	+0.274 (0.094)*	+0.014 (0.067)	-0.060 (0.095)	-1.22 (0.094)	+0.014 (0.067)	3 2 1	8.43%* 22.09%* 68.48%*
Manner of color use	-0.048 (0.145)	-0.078 (0.152)	1.300 (0.106)	+0.457 (0.129)*	+0.337 (0.128)*	+0.086 (0.091)	-0.093 (0.129)	-0.170 (0.128)	-0.019 (0.091)	3 2 1	6.38%* 19.90%* 73.72%*
Overall IT-score	-0.329 (0.301)	-0.041 (0.319)	3.159 (0.221)	1.174 (0.189)*	0.874(0.187)*	0.139 (0.133)	-0.195 (0.189)	-0.554 (0.187)*	0.044 (0.133)	3 2 1	13.33%* 27.15%* 59.52%*

Note. [a] Significant parameters are indicated with an asterisk (*), standard error estimates are placed between brackets; [b] For more information on the coded categories, see Appendix B; [c] RPMM-condition= researcher-provided mind map condition, SGMM-condition= student-generated mind map condition; [d] 3= class-level variance, 2 = student-level variance, 3 =measurement occasion-level variance in the fully unconditional three-level null models.

Table 9

Summary of the Model 2 estimates[a] for the three-level analysis of the traces on the scratch papers[b] for the three conditions[c]

	Pretest score			**Phase 1 (Evolution from pre- to posttest)**			**Phase 2 (Evolution from posttest to retention test)**			**Proportion of the variance at the three levels[d]**
	RPMM condition	**SGMM condition**	**Control condition Intercept β_0**	**RPMM condition**	**SGMM condition**	**Reference Category: Control condition**	**RPMM condition**	**SGMM condition**	**Reference Category: Control condition**	
Hierarchical structure	0.168 (0.214)	-0.087 (0.227)	0.806 (0.158)	0.520 (0.139)*	0.273 (0.137)*	+0.270 (0.098)*	-0.223 (0.139)	-0.449 (0.137)*	0.086 (0.098)	3 15.75%* 2 21.57%* 1 62.68%*
Degree of hierarchy	+0.400 (0.258)	+0.040 (0.274)	0.307 (0.190)	+1.152 (0.181)*	+0.661 (0.180)*	+0.201 (0.128)	-0.464 (0.181)*	-0.602 (0.180)*	+0.140 (0.128)	3 18.59%* 2 13.33%* 1 68.08%*
Color use	0.122 (0.174)	0.022 (0.184)	0.641 (0.128)	0.502 (0.133)*	0.238 (0.132)	+0.300 (0.094)*	-0.211 (0.133)	-0.386 (0.132)*	-0.061 (0.094)	3 11.09%* 2 18.18%* 1 70.73%*
Integrating key words	-0.011 (0.245)	-0.069 (0.259)	1.193 (0.180)	+0.629 (0.175)*	+0.272 (0.173)	+0.305 (0.123)*	-0.267 (0.175)	-0.561 (0.173)*	+0.145 (0.123)	3 11.47%* 2 21.60%* 1 66.93%*
Content coverage	+0.061 (0.174)	+0.019 (0.183)	0.815 (0.127)	-0.175 (0.129)	-0.345 (0.127)*	+0.436 (0.091)*	-0.059 (0.129)	-0.079 (0.127)	-0.004 (0.091)	3 9.01%* 2 27.40%* 1 66.59%*
Overall score	0.329 (0.487)	-0.054 (0.516)	1.868 (0.358)	1.356 (0.308)*	0.594 (0.305)	0.708 (0.217)*	-0.614 (0.308)	-1.061 (0.305)*	0.185 (0.218)	3 15.84%* 2 23.26%* 1 60.90%*

Note. [a] Significant parameters are indicated with an asterisk (*), standard error estimates are placed between brackets; [b] For more information on the coded categories, see Appendix B; [c] RPMM-condition= researcher-provided mind map condition, SGMM-condition= student-generated mind map condition; [d] 3= class-level variance, 2 = student-level variance, 3 =measurement occasion-level variance in the fully unconditional three-level null models.

Table 10

Summary of the Model 2 estimates[a] for the three-level analysis of the free recall scores for the three conditions[b]

	Pretest score			Phase 1 (Evolution from pre- to posttest)			Phase 2 (Evolution from posttest to retention test)			Proportion of the variance at the three levels[c]
	RPMM condition	**SGMM condition**	**Control condition Intercept β_0**	**RPMM condition**	**SGMM condition**	**Reference Category: Control condition**	**RPMM condition**	**SGMM condition**	**Reference Category: Control condition**	
Free recall score	-1.211 (1.738)	1.248 (1.841)	18.102 (1.279)	-1.452 (0.951)	-2.648 (0.939)*	+4.308 (0.677)*	-1.043 (0.948)	-0.834 (0.934)	+1.010 (0.672)	3 13.74%* 2 43.06%* 1 43.20%*

Note. [a] Significant parameters are indicated with an asterisk (*), standard error estimates are placed between brackets; [b] RPMM-condition= researcher-provided mind map condition, SGMM-condition= student-generated mind map condition; [c] 3= class-level variance, 2 = student-level variance, 3 =measurement occasion-level variance in the fully unconditional three-level null models.

Discussion

The strength of researcher-provided mind maps in stimulating spontaneous deep-level text-based learning

Two different instructional approaches of mind mapping (i.e., working with researcher-provided versus student-generated mind maps) were tested in an elementary school-based intervention research to evaluate their value as a meta-learning strategy for stimulating deep-level text-based learning. Two general lines of results are discussed.

First, as to the evolution in students' text-learning strategy use, experimental condition students made significantly greater progress from pre- to posttest in applying overt deep-level strategies as compared to students in the control condition. This finding is also corroborated with the self-reported strategy use analyses, as students from both experimental groups engaged less in rather surface-level paraphrasing activities (i.e., covering up text information and trying to recall it). Students in the RPMM condition show the greatest gains in deep-level observable strategy use regarding the active knowledge organization in the informative text and active text transformation on their scratch paper. Additionally, a more sustained effect was found for RPMM condition students after the end of the intervention period, whereas the deeper-level strategy use of the SGMM condition declined significantly from posttest to retention test. These findings are consistent with previous work pleading for the implementation of predefined worked-examples (e.g., Leopold et al., 2013; Stull & Mayer, 2007). Furthermore, it goes beyond showing that students, who have not received any specific guidelines and practice in constructing graphical summaries, transferred the induced strategies to an independent learning task without any provided mind map or prompted strategy use. This differs from previous studies wherein students are tested after being explicitly asked to execute a task with a provided graphic organizer. It is possible, however, that the finite amount of provided time to study the informative text during data collection has daunted SGMM condition students to engage in deeper-level scratch paper use. Possibly they could estimate more accurately the time it costs to construct a graphical summary, fearing no time would be left to study their summary properly (Merchie & Van Keer, 2012). Additionally, also control condition students made a significant growth in self-reported and observed scratch paper use from pre- to posttest, although less deeply as experimental condition students did. In this respect, control condition students kept a preference to the traditional linear outline format. Their growth can be ascribed to the traditional teaching practices in their classes, as standards from elementary education already stress the importance of cross-curricular 'learning to learn' skills. Therefore, these skills are already stimulated in daily practice to a certain degree in the commercially available teaching manuals.

Second, as to students' evolution in recall performance, control condition students attained a significantly higher free recall score at posttest when contrasted with students from de SGMM condition. No significant gains were found for students in the RPMM condition, compared to the control condition students. Although greater gains for experimental condition students could have been expected, as deeper-level text processing has been found to be related with higher performance (Lahtinen et al., 1997; Nesbit & Adesope, 2006), many possible intermediating factors might explain this result. First, text acquisition might have been influenced by the dual task experimental condition students were focusing on, i.e., text learning and actively activating procedures necessary for text organization and graphical transformation (Griffin, Malone, & Kameenui, 1995). Second, experimental condition students might not yet have reached the final fourth stage of strategy acquisition, wherein the performed strategies also improve learning (Bjorklund, Miller, Coyle, & Slawinski, 1997; Malmberg, Jarvenoja, & Jarvela, 2013). In the first two stages the new strategy is not performed (stage 1) or not produced completely (stage 2). In the third stage, Bjorklund and colleagues (1997) refer to the 'utilization deficiency', were little or no benefits arise from the used strategies. Third, the finite amount of study time might have impede students to learn from their constructed graphical summary or might have affected its quality (Fox, 2009). Fourth, in the light of the Fuzzy Trace Theory, it is possible that experimental condition students learned the text differently, forming different mental representations and memory traces (e.g., focusing on comprehending the gist of the text by graphically summarizing information) than those required in the free recall test (e.g., asking for as much as possible detailed information) (Reyna & Brainerd, 1995; Tzeng, 2010).

Even though output measures are regularly asked for and used in educational research to measure students' gain, Zimmerman et al. (2002) state that students' success is not how much students improve their performance (knowledge acquisition) but rather lies in students' learning processes and how well the new strategies (stimulating knowledge organization and transformation) are applied. In this respect, this study shows that mind mapping is a promising meta-learning strategy to induce and stimulate deep-level text-learning strategy use, especially the instructional approach incorporating researcher-provided mind maps.

Limitations and suggestions for future research

The findings from this study must be complemented with the discussion of some limitations and constraints inherently related to the nature of large-scale school-based intervention research.

A first constraint relates to the used data-gathering methods. In aspiring to query information on a large group of learners, self-report measures were used, to ensure straightforward data gathering and scoring (Braten & Samuelstuen, 2004; Schellings & Van Hout-Wolters, 2011; Schellings, 2011) Additionally, trace methodology provided a more arguably objective set of data on students' overt strategy use (Braten & Samuelstuen, 2007; Winne, 2010). However, some divergence between the self-report and trace analyses must be acknowledged. The significant growth in experimental condition students' traced scratch paper use from pre- to posttest is not reflected, for example, into their self-reports on 'summarizing and schematizing'-activities, which partially cover aspects of this overt strategy use. It might be possible that students were unable to reflect in a way necessary for the correct completion of the questionnaire (Schellings, 2011) and overestimated their scratch paper-strategy use at pretest, revealing no subsequent evolution into their growth analysis. Next to this divergence, not all significant growth evolutions in covert strategy use were straightforwardly interpretable. Consequently, although the combination of self-reports and traces is a clear asset of this study, some applied (meta)cognitive strategies might not be reported on or elicited in the traces. Therefore, these findings point at the need for further data-triangulation and the use of other data-gathering methods to provide more detailed understanding of students' strategy use, in particular their more covert (meta)cognitive text-learning strategy use. In this respect, it would be fruitful to apply the think-aloud methodology on smaller sub-samples in future intervention studies (Schellings et al., 2006; Scott, 2008).

A second constraint of this study relates to the tests used and to the provided time for testing. It was deliberately opted for to use a learning task that acknowledged the context- and domain-specificity of learning from text and provided the engagement in an authentic learning task, as elementary students might experience difficulties reflecting upon a hypothetical situation (Braten & Samuelstuen, 2004, 2007). Furthermore, students were provided with a recall test afterwards, ensuring they were orientated towards learning from text. As a result, teachers were asked to provide two lesson periods for test administration and students had to be concentrated for a considerable amount of time. For this reason, the inclusion of a more comprehensive range of tests for assessing performance (e.g., transfer tests, comprehension tests) or more individual characteristics (e.g., verbal and spatial ability tests) was difficult, as this would be additionally even more time-consuming. Nevertheless, the shortcomings in the use of immediate and free recall tests (e.g., assessment of mainly factual knowledge) must be acknowledged (Robinson, 1998) and future research should include other tests. In particular, test developers are encouraged to compose a standardized test. In contrast with standardized measurements for reading comprehension largely focusing on narrative texts, similar tests measuring students' text-learning strategies in informative texts for late elementary grades are not forehand.

A third constraint relates to the assessment of fidelity to treatment. Although this assessment was executed through the evaluation of structured protocols and questionnaires, two general remarks can be made. First, it might have been very valuable to assess teachers' specific competencies required for successful intervention implementation, i.e., teachers mind mapping skills in the SGMM condition. Although this was largely offset by teachers' training, the offering of background information, and worked-example mind maps included into their manuals' correction key, teachers' mind map skills might have been of influence. Furthermore, teachers were not explicitly questioned about balancing teaching content and modeling strategy instruction, which might have been difficult to do (Vaughn et al., 2013). Future mind map research, should take these possible influencing factors into account. Second, no systematic direct observations were executed to compare actual implementation with the established criteria (Smith et al., 2007). Various factors were prohibitive to carry out direct observations in this study, such as the expensive form of this data collection (i.e., costs related to the employment and training of personal attending the intervention sessions and the time-consuming coding) (Swanson et al., 2013) and the desire to minimize the impact of researchers' attendance in the authentic classroom settings with their naturally occurring incidents. However, truthfully acknowledging the value of direct observations to obtain treatment fidelity measures, future research should keep on searching for valid means to obtain valid treatment fidelity data in relation to these budgetary considerations.

Contributions and implications

Today's educational practice requires effective teaching approaches for stimulating text-based learning from early adolescence on (Alexander & Res, 2012; Schlag & Ploetzner, 2011). In response to this call, this study focused on the instructional use of mind maps, which are already frequently employed in classrooms. However their instructional use in current educational practice misses a clear scientific and evidence-based underpinning. In this respect, this study extends prior work and pioneers in some important ways. First, in contrast with the previously rather short-time investigated modest sample sizes in higher educational settings (e.g., Abi-El-Mona & Adb-El-Khalick, 2010; Dhindsa, Kasim, & Anderson, 2011; Farrand et al., 2002), this study is executed longitudinally on a large scale, studying students from thirty-five classes from 17 different elementary schools. Second, the study includes a randomized assignment of two experimental and one control condition. Multilevel piecewise growth modeling was applied to analyze students' growth in strategy use, explicitly taking into account their hierarchical nesting in classes. Third, two different instructional approaches of mind mapping were implemented during a whole semester by students' regular classroom teachers into students' intact classroom settings. Mind mapping is herein conceived as more than a simple associative tool or a single strategy (e.g., Brinkmann, 2003; Davies, 2011; Moi & Lian, 2007). It is broadly conceptualized as a meta-learning strategy comprising sequentially ordered phases to induce a more comprehensive range of text-learning strategies.

Some important implications resulting from this study can be translated to educational practice and research. First, this study wants to encourage elementary school teachers to implement mind mapping as a meta-learning strategy into their content courses. In particular, incorporating provided mind maps provide a promising means to stimulate students' autonomous text-based learning. The present study shows that practice matters. In this respect, it is of highest importance that this strategy instruction does not occur occasionally, but takes place in a consistent way on a regular basis. Only in this way, it can be assured that the induced text-learning strategies by teachers' modeling are systematically initiated, recapitulated, and practiced towards a more self-regulated, autonomous, and deeper-level strategy use. In relation to this, this study also hopes to inspire instructional designers to go beyond the inclusion of a single mind map-lesson or chapter into their existing teaching methods. In this respect, they are encouraged to implement worked-out mind maps with an increasing level of difficulty and accompanied with student activities simulating authentic learning situations, in dialogue with mind map- and subject matter-experts.

As to the implications for educational research, a final concrete research suggestion, in addition to those already mentioned above, is to investigate an extra hierarchical level (i.e., teachers having the same principals) into multilevel analyses. As this might have influenced teachers' project-commitment and sustainability (Mishna, Muskat, & Cook, 2012), it seems worthwhile to take this into account in future research. Next to these concrete suggestions, we would like to emphasize some actions that were undertaken to address and anticipate on potential setbacks and which were highly appreciated by the participants. They could be accounted for in future research, to keep schools motivated to participate in interventionresearch. First, principals and teachers valued the individual school visits for both providing personalized project-information and teacher training into their daily staffroom. These visits enhanced project approval and cooperation and made project preparation as accessible as possible. Furthermore, the provision of all necessary school material and the incorporation of the lesson-series into the regular courses and the general school calendar enhanced participation. To thank the participants for their project-participation each of the principals, teachers and students received a personal appreciation. Finally, teachers were informed about students' progress by a feedback report afterwards, outlining the class' study results and some general overall findings. In this way, good relationships with schools are maintained.

To conclude, the present study proposes an effective educational teaching practice and shows that the instructional use of mind maps in late elementary education is a powerful technique, equipping students with essential text-learning strategies necessary for school and future learning. It is believed that the added value of intervention research in early adolescence (i.e., investigating students in an ecologically valid school context) exceeds the potential challenges and educational researchers should prioritize school-based intervention research to provide valid scientific underpinnings of contemporary educational practices.

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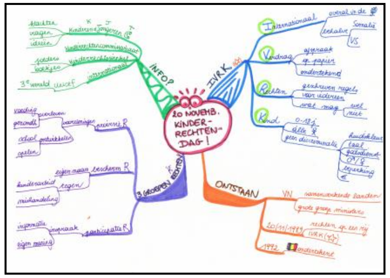
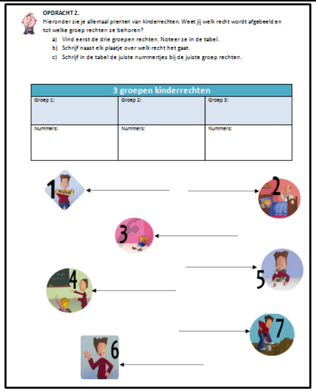
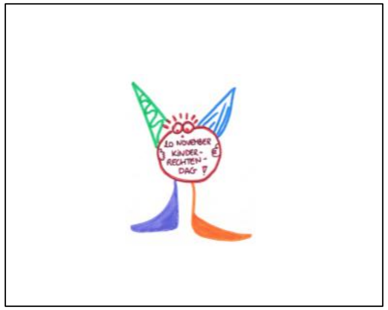
Appendix A

Example of a classroom assignment on children's' rights (lesson 5) in both strategy programs illustrating the instructional approaches in experimental condition 1 and 2

Instructional approach 1: Working with researcher-provided mind maps

Informative text	Classroom assignment 1	Mind map-worksheet with researcher-provided MM	Classroom assignment 2	
	(1) Getting an overview: Scan and read the text, clarify incomprehension. (2) Identifying key information: highlight relevant key words.			(3) Working with mind maps: Active knowledge transformation → Search for three groups of children's rights in the mind map and write them down in the table. → Which rights are the pictures illustrating? Write down. Match the numbered rights with the corresponding group in the table. (4) Process and product evaluation

Instructional approach 2: Working with student-generated mind maps

Informative text	Classroom assignment 1	Mind map-worksheet for student-generated MM	Classroom assignment 2	
	(1) Getting an overview: Scan and read the text, clarify incomprehension. (2) Identifying key information: highlight relevant key words.			(3) Working with mind maps: Active knowledge transformation Challenge: Can you complete the following tasks within the next 35 minutes? → Find all main branches. → Elaborate at least one main branch with related sub-branches using most important key words. → Include 1 cluster, 1 arrow, or connector. → Respect all specific mind map-characteristics Indicate whether or not you think the challenge will succeed. (4) Process and product evaluation

Appendix B

Scoring rubric for the traces on the informative text and scratch paper

Informative text trace					
	0	1	2	3	4
(Sub)title markings	Not applicable (no text markings)	Only the title is marked	Marked some or all subtitles	Marked title and some subtitles	Marked title and subtitles
Figure markings	Not applicable (no figure markings)	Markings in one figure	Markings in several figures	Markings and/or annotation in several figures	A combination of markings and annotations in one or more figures
Distinguishing main and subideas	Not applicable (no text markings)	There are predominantly complete sentences or fairly long text parts marked	There are predominantly key phrases highlighted, with now and then separate keywords	There are predominantly short key phrases and key words marked. However, the student still has some difficulty in selecting the most important information	Throughout the text relevant key words are marked, reflecting the main ideas of the text and most important text information
Quantity of the markings	Not applicable (no text markings)	Relatively few	Half of the text	Relatively much	Almost everything
Color quantity	Not applicable (no text markings)	1 color used	2 colors used	3 colors used	More than 4 colors used
Distinguishing main and sub ideas by means of different colors	Not applicable (no text markings)	Only one color is used during highlighting	There is more than one color used, but the distinction between main and sub ideas is not clear	Different colors are used, however the distinction between main and sub ideas is sometimes made still inconsistently Or: Every paragraph is marked with a different color, but not always consistently	There is a consistent use of different colors throughout the text, reflecting the differences between main and sub ideas. Or: Every paragraph is consistently marked with a different color
Manner of color use	Not applicable (no text markings)	Througout the text, the same color is used	Different color use, dependent on title, subtitle and paragraph information	Every text paragraph is marked with a different color	Combination of marking methods (e.g., marking text and underlining)

Scratch paper trace					
	0	1	2	3	4
Hierarchical structure	Not applicable (no scratch paper use)	Linear unstructured summary	Linear structured summary	Graphical unstructured summary	Graphical structured summary
Hierarchical degree	Not applicable (no scratch paper use)	Columns scheme	Sequential structure without hierarchical structure	Tree structure	Hierarchical and radial mind map structure
Color use	Not applicable (no scratch paper use)	1 color used	2 colors used	3 colors used	More than 4 colors used
Integrating key words	Not applicable (no scratch paper use)	There are predominantly complete sentences or fairly long text parts copied on the scratch paper	There are predominantly phrases copied on the scratch paper, reformulated in own words	There are predominantly short key phrases copied on the scratch paper	There are predominantly key words copied on the scratch paper
Content coverage	Not applicable (no scratch paper use)	Little content coverage	Average content coverage	Good content coverage	Almost complete content coverage

9 Spontaneous mind map use and learning from texts: The role of instruction and student characteristics

This chapter is based on:

Merchie, E., & Van Keer, H. (2012). Spontaneous mind map use and learning from texts: The role of instruction and student characteristics. In Z. Bekirogullari (Ed.), Procedia Social and Behavioral Sciences (Vol. 69, pp. 1387–1394). doi: 10.1016/j.sbspro.2012.12.077

Chapter 9
Spontaneous mind map use and learning from texts: The role of instruction and student characteristics

Abstract

Independently processing and learning informative study texts becomes increasingly important from the age of 11-13, when the focus shifts from 'learning to read' to 'reading to learn'. The need arises to support students in dealing with study texts and stimulating generative study strategies promoting active knowledge transformation. This study shows that a mind map intervention can prompt fifth and sixth graders to use mind maps during text learning. Furthermore, the mind map instruction method, students' gender, mind map appreciation, and self-efficacy seem to influence their spontaneous use. No significant differences were found on immediate free text recall.

Introduction

Working with mind maps: Stimulating active knowledge transformation

Currently, students are continuously challenged by the exponential knowledge increase in our information society and the large amounts of information they have to process and learn independently. This becomes increasingly important from the age of 11-13, when the focus shifts from 'learning how to read' to 'reading to learn' (Bakken & Whedon, 2002; Hall-Kenyon & Black, 2010). From this point on, students are expected to spend more and more time on obtaining new content from their textbooks (Hall-Kenyon & Black, 2010; Schellings & Broekkamp, 2011). Consequently, the establishment of a good study method is crucial to meet this more complex study requirements (Meneghetti, De Beni, & Cornoldi, 2007). In this respect, the need arises from late elementary education on to stimulate the development of specific learning strategies aimed at effectively processing and learning from texts (Perels, Gürthler, & Schmitz, 2005; Pintrich, 2004; Rawson & Dunlosky, 2007).

Previous research indicates that the use of generative study strategies (i.e., strategies evoking active knowledge transformation) rather than non-generative strategies (e.g., repeatedly reading or literally copying texts) are associated with higher performance when studying (e.g., Davies, 2011; Lahtinen, Lonka, & Lindblom-Ylänne, 1997; Nesbit & Adesope, 2006; Weinstein & Mayer, 1986). Working with graphic organizers (GO), such as concept maps (Novak, 2002), thinking maps (Hyerle, 1996), and mind maps (Buzan, 1974; Buzan, 2005), is such a specific generative strategy transforming linear text into a graphical representation. Graphic organizers are spatial arrangements of words (or word clusters) representing the conceptual organization of a text (Stull & Mayer, 2007). As they clarify the relationships between important concepts in a text and illuminate big ideas (Banikowski, 1999; Crawford & Carnine, 2000), they can help students process, structure and acquire the large amounts of information they are confronted with (Dansereau & Simpson, 2009; Vekiri, 2002). When students are reading, analyzing, or constructing graphic organizers, they are cognitively engaged in searching connections among the concepts and thus deeply processing the learning material. By doing this, they develop a general capacity to structure and organize knowledge, which in turn promotes generative and deep text processing (Nesbit & Adesope, 2006; Schnotz, 2002). Several general theories underpin the use of graphic organizers. The Dual Coding Theory (Paivio, 1991) and the Cognitive Load Theory (Sweller & Chandler, 1994; Sweller, van Merriënboer, & Paas, 1998) point to advantages in the decrease of cognitive load and the recall of text information due to the simplification of the complex relationships and ideas in the text. As there is a growing need of purposive interventions to support children in learning from texts, familiarizing them with graphic organizers during content courses seems an important step towards stimulating active knowledge transformation. Therefore, in this study the possibilities of working with mind maps as a specific type of graphic organizer are explored.

Mind maps (MM) (Buzan, 1974) are already frequently used in educational practice. In a mind map, one key concept, often represented as an image, is located at the middle of the page. From this central topic, several related main topics in different colors are radiated out in the shape of thick branches. Attached to these main branches, other smaller branches represent related concepts. In this way, related words are associated through curved main and sub-branches. Mind maps can be further enriched by colors, images, codes, arrows, and dimension to reflect personal interest and individuality (Buzan, 2005). The specific mind map characteristics are grounded and supported by research findings from both educational as well as brain research (Anderson & Hidde, 1971; Budd, 2004; Haber, 1970; Mento, Martinelli, & Jones, 1999; Michalko, 2003). Beside these specific characteristics and the theories referred to above several studies indicate that mind maps are effective in helping children to structure, summarize, and study subject matter (Brinkmann, 2003; Farrand, Hussain, & Hennessy, 2002). Most of these studies focus however on science subjects in secondary or higher education, although the importance of the acquisition of information processing skills in earlier grades is frequently stressed (Guastello, Beasley, & Sinatra, 2000; Rawson, 2000). Furthermore, in these previous studies only a very restricted period of mind map training generally proceeds testing. As goal-oriented interventions can stimulate strategy use from elementary grade on (Dignath & Büttner, 2008; Lee, Lan, Hamman, & Hendricks, 2008), the present study investigates the impact of a long-term mind map intervention in elementary education on active knowledge transformation during an independent learning task.

The role of instruction and student characteristics in spontaneous mind map use during learning from text

There are numerous factors that play a role in the effectiveness of working with mind maps in elementary grades. In this respect, the present study explicitly focusses on specific class and student-level variables that might influence students' spontaneous use of mind mapping. First, the specific instruction can play a crucial role when working with maps. In research literature, a well-known discussion is going on about working with researcher-provided versus student-generated maps (Kirschner, Sweller, & Clark, 2006; Lee & Nelson, 2005; Stull & Mayer, 2007). On the one hand it is argued that stimulating students to create mind maps themselves permits them to actively engage in selecting and organizing the new subject matter in relation to their existing knowledge structures (McCagg & Dansereau, 1991; Stull & Mayer, 2007). On the other hand, researchers mainly inspired by cognitive load research (Sweller & Chandler, 1994) are convinced that researcher-provided maps provide more opportunities to learn from a worked-example (Kirschner et al., 2006; Stull & Mayer, 2007). However, very little is known about the extent to which the different instructional approaches elicit the spontaneous use of this technique for text studying. Most students participating in previous studies were tested after being explicitly asked to read or learn a text passage with an researcher-provided GO or when asked to construct one themselves (Stull & Mayer, 2007). Getting insight into this question can inform educational practice on how to integrate mind maps effectively into their content courses. In this respect, it can be hypothesized that students taught to work with student-generated mind maps (SGMM) rather than with researcher-provided mind maps (RPMM) will be more inclined to autonomously create mind maps during independent text studying.

In addition to the instructional approach, various learner characteristics may affect students' spontaneous mind map use as well. A first aspect taken into account in the present study are gender differences (Rozendaal, Minnaert, & Boekaerts, 2003; Slotte, Lonka, & Lindblom-Ylänne, 2001). In the research of Slotte et al. (2001) the hypothesis that boys are more inclined to transform linear text into graphic maps due to their higher spatial abilities was countered. As research on gender differences regarding organizational strategy use is not very large and still inconclusive (Rozendaal et al., 2003), this will be specifically included in the study. Secondly, also motivational factors might encourage or discourage students to use the mind map technique spontaneously (Goodnough & Woods, 2002; Schnotz, 2002). In this respect, two factors are addressed. A first important prerequisite towards spontaneous use of a certain learning strategy is the student's personal appreciation ascribed to this particular learning strategy after working with it during daily educational practice. Furthermore, also students' self-efficacy regarding mind mapping can influence spontaneous use. Based on previous research (Bandura, Barbaranelli, Caprara, & Pastorelli, 1996; Linnenbrink & Pintrich, 2002) and adjusted to this research context, this can be defined as the learners' judgment concerning their task-specific capabilities to create a mind map from a text. It is expected that students who create a mind map during text learning will report higher on mind map appreciation and mind map self-efficacy.

In sum, the aim of the present study was to explore (a) whether a mind map intervention can stimulate fifth and sixth graders to use mind maps spontaneously during independent text learning, (b) to what extent the instructional approach and student characteristics play a role in their spontaneous use of mind maps, and (c) whether there is any difference in free text recall between conditions and between students who did and who did not create a mind map during independent text studying.

Method

Design

A quasi-experimental pre- and posttest design was applied in authentic fifth and sixth-grade classes. The focus lies on time interval (pretest and posttest) and the research condition (two experimental conditions and one control condition). The main goal of both experimental conditions was to stimulate active knowledge transformation of informative texts in a structured way. Therefore, a previously pilot-tested mind map training of 10 weeks (Merchie & Van Keer, 2013) was embedded in social study and science courses during regular classroom hours by the regular classroom teachers. The mind map training consisted of 10 lessons of 50 minutes. In the first experimental condition working with researcher-provided mind maps, active knowledge transformation was stimulated through different types of exercises (e.g., fill in the blank, open questions, searching for answers in the mind map) that pupils had to complete on the basis of the informative texts and the accompanied researcher-provided mind maps. In the second experimental condition teaching students to self-generate mind maps, students processed the subject matter in informative texts gradually by constructing mind maps themselves. The classes in the control condition received no explicit training in active knowledge transformation of informative texts by means of mind maps.

Participants

This study was carried out with 20 fifth and 22 sixth-grade classes (*n*=644), respectively 213 students in the researcher-provided mind map condition, 219 in the student-generated mind map condition and 212 in the control condition. Table 1 represents the descriptive information concerning grade and gender across conditions.

Table 1
Overview of the participants across conditions

		Researcher-provided mind map condition		Student-generated mind map condition		Control condition	
		n	%	*n*	%	*n*	%
Gender	Male	108	50.9	108	49.3	131	61.5
	Female	104	49.1	111	50.7	82	38.5
Grade	Fifth grade	95	44.8	92	42.0	106	49.8
	Sixth grade	117	55.2	127	58.0	107	50.2

Instruments

Students' spontaneous use of mind maps while studying text was assessed in a pre- and posttest by a specific learning task administered in class. Students were asked to study an informative text (500 words) for 30 minutes as if they would prepare for a test. The two texts entitled 'The wonderful world of seahorses (pretest) and meerkats (posttest)' consisted of six central topics: general information, body parts, living environment, eating habits, reproduction, and interesting facts. Text readability and difficulty was evaluated by an expert, an elementary school teacher, and an elementary school student. While studying, students were free to use scratch paper and were not prompted to make a mind map in order to assure that the strategy was used spontaneously (Veenman, 2011). The scratch papers were collected afterwards to code with a 0 or 1 according to whether or not a mind map was constructed during text learning.

After handing in their learning materials, text acquisition was tested with a free recall test. Students were asked to write everything down they still remembered from the text. The recall score represents the percentage of recalled text information.

After completing the recall test, students in the experimental conditions completed a questionnaire concerning students' mind map appreciation and mind map self-efficacy. The questionnaire consists of 9 items on a 5-point Likert scale and contains 2 subscales: mind map appreciation (5 items, α=.86, e.g., 'Mind maps help me to understand and learn an informative text') and mind map self-efficacy (4 items, α=.71, e.g., 'I am good in making a mind map').

Data analysis

Chi-square analyses were used in order to compare the spontaneous mind map use during text studying across conditions and gender. Further, Independent Sample t-tests were used to verify differences between mind map appreciation and mind map self-efficacy in the experimental conditions, between boys and girls and between pupils who did and did not construct a mind map during text learning. A repeated measures analysis of variance was applied to analyze text recall differences between the three conditions.

Results and discussion

Results from the chi-square analysis show no differences in spontaneous mind map use across the conditions at pretest (χ^2=5.17, p=.076). Only a few students spontaneously construct mind maps during informative text learning before the onset of the intervention. When looking at the posttest results however, a significant relationship between spontaneous mind map use and condition is shown (χ^2=74.65, p<.001). In the control condition only 11.7% of the students created a mind map during text studying, compared to 32,1% in the student-generated mind map (SGMM) condition, and 51,5% in the researcher-provided mind map (RPMM) condition (Figure 1). These results lend to support that an intervention whereby informative texts are processed by means of mind maps during regular class hours can prompt students to spontaneously transform their linear texts into graphical representations during independent text learning. Against expectations, more students in the researcher-provided mind map condition spontaneously constructed a mind map than students who gradually learned to make mind maps themselves. This finding is somewhat surprising, as SGMM condition students got more explicit guidelines and practice in the construction of mind maps during the intervention period. A tentative explanation for this finding could be that SGMM condition students were less inclined to create a mind map since they could make more accurate estimations of the time it cost to mind map the text. This was confirmed by a student in an informal interview after the test: *'I knew there was only limited time for studying the text so by the time I would have finished my mind map, no time would be left to review and study it'*. This student however did not realize that by actively creating the mind map, the subject matter is processed and practiced in the meantime. Possibly, when students were given the time to study the text at their own pace, more SGMM condition students would have created a mind map. More profound qualitative research in this case is necessary to determine the motives that drive or hinder the spontaneous use of mind maps in both experimental conditions.

When narrowing the focus down to the gender of the mind map users in the posttest, the analysis show significant relations between gender and spontaneous mind map use in both the researcher-provided (χ^2=13.91, p<.001) and student-generated mind map condition (χ^2=14.47, p<.001). With respectively 62% (RP) and 70% (SG) female mind mappers, it were predominantly girls who drew a mind map while studying text. In corroboration with the research of Slotte et al. (2001), the hypothesis that boys intend more to transform linear text into graphic maps was not supported. Future studies should unravel why girls seem more inclined to create mind maps. Are they more attracted by the technique due to the specific mind map characteristics (e.g., use of colors, figures)? Is there any link with gender differences in creativity or spatial ability?

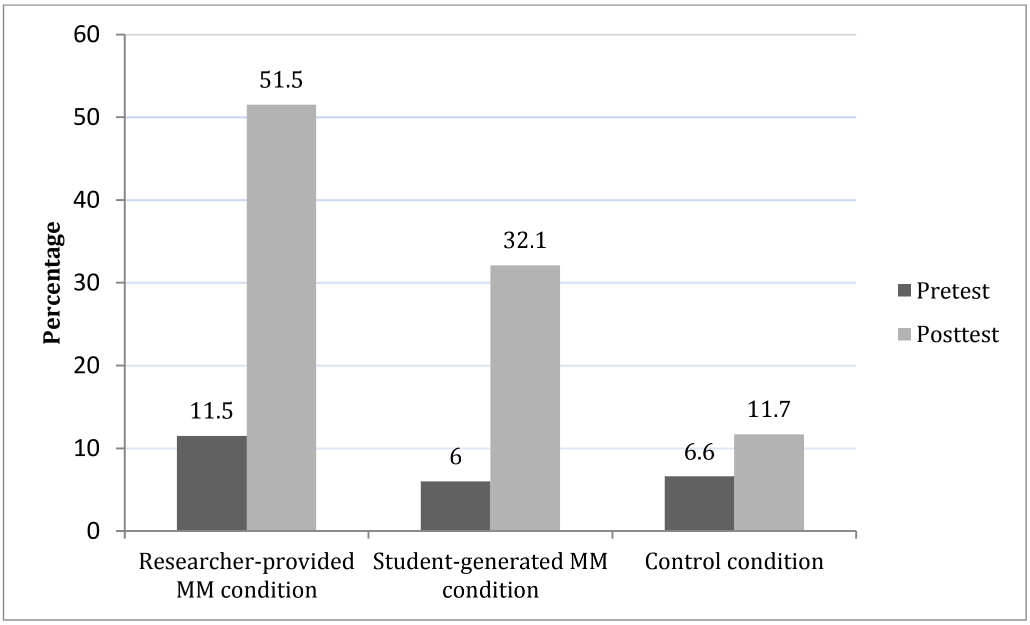


Figure 2. Percentage of students spontaneously making a mind map during pre- and posttest.

To verify differences in mind map appreciation and mind map self-efficacy between conditions and gender, first general scores across the two mind map conditions were compared. Results of the independent-samples t-test show significant differences as students in the researcher-provided condition overall report higher scores on both mind map appreciation ($t(412) = 6.24$, $p<.001$) and mind map self-efficacy ($t(414) = 6.68$, $p<.001$). In this respect, RPMM condition students do not only appreciate the technique more and are more intended to use it in the future, they also judge themselves as more competent in creating mind maps. Again, this is a remarkable finding since they processed texts with worked-examples and were not taught the technique explicitly. On the other hand, this can explain the finding that students from the RPMM condition students made more use of the mind map technique for text studying. When focusing on students who did or did not spontaneously created a mind map during the posttest, the mind map users do appreciate using mind maps more ($t(409) = -6.42$, $p<.001$) and judge themselves as more competent in creating mind maps ($t(411) = -4.13$, $p<.001$). This result was in line with expectations, as positively motivated beliefs are associated with higher strategy use (Winne, 2010). With regard to gender differences it was found that predominantly girls drew a mind map. In line with this result, girls do appreciate the technique more in both mind map conditions ($t(411) = -3.24$, $p=.001$). There were however no gender differences concerning students' mind map self-efficacy ($t(413) = -0.34$, $p=.736$).

Finally, as previous research indicated that the use of generative study strategies, such as mind mapping, is associated with higher performance (e.g., Lahtinen et al., 1997), effects on students' free text recall were studied. No significant differences were found, however, between the conditions ($F(582,2) = 1.94$, $p=0.144$) and between students who did or did not drew a mind map ($F(577,1) = .002$, $p=0.968$). This result might be due to the fact that the strategy was of no direct help for immediate global text recall. Another explanation might be that students were tested immediately after learning and no delayed recall test was administered (Stull & Mayer, 2007). Furthermore, because of the relatively short time span wherein students had to study the text, it is also possible that mind map users did not gain advantage of their strategy to study the text by mind mapping. This presumption is based on the finding that the majority of the mind maps on the scratch papers were unfinished. In addition to administering a delayed recall test and providing more study time, another recommendation for future research is the inclusion of a recall test consisting of different question types (e.g., text-based questions, inference questions) (McNamara & Kintsch, 1996) to gain insight in the specific relationship between mind mapping and text recall. It must also be noted that the present explorative study focused on one specific direct observable overt study strategy (i.e., using mind maps). Therefore, future studies should also take into account covert study strategies, such as mentally associating or combining ideas without writing them down (Kardash & Amlund, 1991) and their effect on learning from text with or without mind maps.

In conclusion, the results of the present study support the idea that working with mind maps during daily educational practice can stimulate fifth and sixth graders to actively transform linear text by means of mind maps. This can be seen as a step towards encouraging the use of more generative study strategies in elementary school. Students who spontaneously drew mind maps during learning from texts were predominantly girls and mainly students working with researcher-provided mind maps during the intervention period. These groups also appreciated the technique more. This study represents a start in investigating the use of mind maps in elementary grades, hoping to inspire other educational researchers to replicate, confirm, or broaden our findings based on the suggestions for future research.

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10 General conclusion and discussion

Chapter 10
General conclusion and discussion

Abstract

This dissertation builds upon two important research lines, i.e., the assessment and profiling of text-learning strategy use, including graphical summarization skills, in late elementary education students on the one hand, and fostering generative strategy use with a mind map strategy instruction intervention on the other hand. This final chapter provides a comprehensive discussion of the results obtained in the different empirical studies, presented in chapter 2 to 9. Furthermore, limitations related to the conceptualization and inclusion of the studied variables on the one hand (i.e., associated with student characteristics, characteristics of the text and the graphical summary, and the instructional context) and to the applied methodology on the other hand are considered. Based on these limitations, future research aspirations are proposed. This dissertation concludes with implications for theory, research, educational practice, and policy.

Introduction

In the introductory chapter of this dissertation (chapter 1), the importance of stimulating a broad repertoire of text-learning strategies was discussed. Two important considerations were drawn from an overview of relevant theories regarding self-regulated learning in general (e.g., Boekaerts, 1999; Pintrich, 2000; Winne, 1996) and learning strategy research in particular (i.e., 'Good Strategy User model'; Pressley, Borkowski, & Schneider, 1987; 'Selection Organization Integration model'; Mayer, 1996; 'Model of Domain Learning'; Alexander, 1998; and the 'Model of Strategic learner'; Weinstein, Jung, & Acee, 2011). First, effective learners are strategic learners. To be successful in the 21st century, students should possess a flexible set of text-learning strategies, that are strategies to process and learn informative texts. These strategies can been categorized in various ways (i.e., according to their nature, level or depth, perceptibility or learning phase wherein they are applied) and can be combined differently into students' learner profile of strategy repertoire. Graphical summarization was identified as an important deep-level generative text-learning strategy in students' strategy repertoire. In a graphical summary multi-paragraph text information is summarized and transformed into a visually coherent and hierarchically organized spatial structure. As to the second consideration, all theoretical models point at the need for educational techniques or express guidelines to introduce strategic learning to students. Working with mind maps used as graphical summaries was found to be promising to this end from both a theoretical, empirical, and practical perspective.

Two lines of research were delineated from these considerations in our aim to encourage pre-adolescents text-learning strategies in late elementary education by means of mind mapping.

(1) A first research line builds upon the importance of appropriate measurement instruments to assess and profile text-learning strategies in late elementary grades. These are crucial to document on students' initial strategy base and to be able to document precisely on potential intervention effects (Boekaerts & Corno, 2005; Donker, de Boer, Kostons, Dignath van Ewijk, & van der Werf, 2014; Pressley, Graham & Harris, 2006). Such instruments are currently lacking in educational research. Therefore, a first research line focused on the *assessment and profiling of text-learning strategies* in general, and of graphical summarization skills in particular. In this respect, measurement instruments were developed from different methodological perspectives. Studies described in chapter 2 to 4 fit in with this first research line.

(2) A second research line focused on *fostering text-learning strategies by means of a mind map strategy instruction intervention*, building on the promising role of using graphic organizers such as mind maps to stimulate text-based learning. Studies described in chapter 5 to 9 fit in with this second research line. Two sub goals were included within this second research line.

- *Sub goal 1.* A first sub goal was to investigate mind mapping as an organizational learning strategy. Here, mind mapping is used to initiate students' graphical summarization skills, that is their ability to transform linear multi-paragraph texts into a graphical summary.
- *Sub goal 2.* A second sub goal was to investigate mind mapping as a meta-learning strategy. Here, mind mapping is used in strategy instruction to induce the spontaneous application of a larger repertoire of text-learning strategies during independent text learning, entailing both cognitive and metacognitive text-learning strategies.

Within both sub goals, also the following class- and student-level characteristics were investigated:

- The role of the instructional approach at class-level. In this respect, it is investigated whether different effects are found when incorporating either researcher-provided or student-generated mind maps into the strategy instruction.
- The role of student characteristics at student-level. In this respect, gender, grade, home language, achievement level, and learner profile were studied.

In the subsequent paragraphs the results from the empirical studies will be discussed. The Appendix included at the end of this chapter, provides a general overview of the obtained main results, study limitations, suggestions for future research and implications.

Overview and discussion of the main results

Research line 1: Assessing and profiling text-learning strategy use in late elementary education

The first line of research focussed on the assessment and profiling of text-learning strategies in pre-adolescence. Since standardized measures for this age group are currently lacking in educational research, it was a prerequisite to develop appropriate measurement instruments. Three empirical studies, described in chapter 2, 3 and 4 are related to this first line of research.

Chapter 2 presents a newly developed inventory to assess students' strategy use when learning from informative texts at the end of the elementary level, i.e., the 'Text-Learning Strategies Inventory' (TLSI). This inventory was based on (a) a theoretical exploration of learning strategy categorizations (e.g., Lahtinen, Lonka, & Lindblom-Ylänne, 1997; Wade, Trathen, & Schraw, 1990; Weinstein, Jung, & Acee, 2010) and (b) existing questionnaires regarding self-regulated learning (e.g., Biggs, 1987; Vandevelde, Van Keer, & Rosseel, 2013;) and strategy use (e.g., Entwistle & McCune, 2004; Samuelstuen & Braten, 2007; Weinstein & Palmer, 2002). An item pool of 66 self-report items was tailored to our specific target group (i.e., fifth and sixth graders) and specific learning context (i.e., independently studying an informative text). Following the recommendations in the literature on the large-scale assessment of learning strategies (Braten & Samuelstuen, 2004; Schellings, 2011), the inventory was task-specific as it was immediately administrated after a researcher-developed study task (i.e., studying a 491-word informative text). The self-report inventory was first administered in a sample of 896 fifth and sixth graders. A parallel and exploratory factor analysis was conducted, resulting in a 9 factor-model retaining 37 items. This model was also confirmed by a confirmatory factor analysis on a second independent sample, consisting of 644 fifth and sixth graders (i.e., the pretest data of the study reported in chapter 8). Also measurement invariance across gender was confirmed. The nine identified subscales can largely be classified according to the existing learning strategy categorization systems based upon their nature and perceptibility. In this respect, six subscales reflect cognitive strategies, including both overt (i.e., text-noting strategies such as summarizing and schematizing, underlining) and covert strategies (i.e., mental-learning strategies such as rereading, paraphrasing, linking with prior knowledge, studying titles and pictures) (Kardash & Amlund, 1991; Lahtinen et al., 1997; Weinstein et al., 2011). Three subscales reflect metacognitive strategies (i.e., planful approach, monitoring, and self-evaluation) (Schraw, 1998). Notwithstanding the resemblance with existing categorization systems, there are also some dissimilarities. For example, the category 'rehearsal strategies' from the literature (Weinstein & Mayer, 1986) was not identified as a distinct category in the present study. Instead, items reflecting these rehearsal strategies were included into the cognitive subscales of 'summarizing and schematizing', 'rereading', and 'paraphrasing' and consequently found to be related to these specific study strategies. The analysis also did not confirm the strict distinction between surface-level and deep-level strategies referred to in the literature (Alexander, Dinsmore, Parkinson, & Winterzs, 2011; Ausubel, 1968). Here again, some subscales in the present results seem to include both surface- and deep-level strategies. For example, the subscale 'summarizing and schematizing' includes surface-level (e.g., copying information) as well as deep-level strategies (e.g., schematizing) (Kardash & Amlund, 1991; Lahtinen et al., 1997; Wade et al., 1990; Weinstein et al., 2011). An explanation for this finding might be found in the light of the Model of Domain Learning (Alexander, 1998). In this respect, Alexander, Murphy, Woods, Duhon, & Parker (1997) state that acclimated or novice learners still mostly engage in surface-level processing and rather limitedly in deep-level strategies. As such, it is possible that surface- and deep-level strategies are still intertwined at this age and therefore not captured as two distinct to be differentiated factors in the factor analyses. Hence, next to corraborating existing categorization systems, this study also provides new insights into the text-learning strategy use of late elementary students.

Furthermore in chapter 2, students were assigned to one of four different learner profiles according to their self-reported text-learning strategy use, by means of hierarchical cluster analysis (sample 1; 896 students). This cluster solution was validated with a k-means cluster analysis and chi-square analysis on respectively the self-reports and study traces of a second indepent sample (sample 2; 644 students). This resulted in the identification of four learner profiles: the integrated strategy user (ISU), the information organizer (IO), the mental learner (ML), and the memorizer (MEM) In both samples, a third of the students was identified as memorizers, which can be regarded as a less preferable profile as these learners heavily rely on merely using one rather surface-level text-learning strategy. Also the relationship between cluster membership and students' free text recall was investigated, indicating a marginally significant preference for the integrated strategy user, showing the highest text recall scores. Furthemore, the analysis indicated that more girls than boys were identified as integrated strategy users, and more boys than girls as mental learners and memorizers.

As some concerns are associated with using self-reports (e.g., Veenman, 2011) and methodological data-triangulation is advised in literature (e.g., Denzin, 2009; Boekaerts & Corno, 2005), different methodological approaches were applied in chapter 3 to assess and profile text-learning strategy use. More particularly, text-learning strategy use in general and graphical summarization skills in particular were assessed by means of think aloud methodology, trace methodology, and pen movement analysis. These methodologies were applied in a smaller-scale study (n=20). As to the think-aloud methodology, students were asked to think aloud while individually performing (a) the researcher-developed study task, described in chapter 2, and (b) a graphical summarization task (i.e., graphically summarizing an informative text paragraph) by means of a digitial writing pen. To analyze students' think aloud transcripts during text learning, a text-learning strategy protocol was developed in line with the theoretical classification systems (see Appendix in chapter 3). Furthemore, trace methodology (i.e., analyzing the quantity and quality of students' traces) was applied on their informative texts, scratch papers, and graphical summaries (Braten & Samuelstuen, 2007; Winne, 2010). Based on guidelines in the literature (Meier, Rich, & Caddy, 2006; Nitko & Brookhart, 2007), analytic scoring rubrics with high interrater reliability were developed. Descriptive analyses revealed that students' strategic and deep-level strategy use while learning from text is still in its infancy. Further in this chapter, the existence of different strategy repertoires was explored by descriptive analyses on the occurrence of students' applied text-learning strategies. Four strategy repertoire groups were identified, i.e., (1) a first group possessing a very small strategy repertoire (*n*=7), (2) a second group frequently using one single text-learning strategy (*n*=3), (3) a third group adressing a richer and deep-level though not strategically combined strategy repertoire (*n*=6), and (4) a fourth group strategically combining a richer text-learning strategy repertoire (*n*=4). This classification was confirmed by a hierarchical cluster analysis. In this sample, half of the students thus posses a very limited strategy repertoire with unvaried strategy use. Further, students' intitial graphical summarization skills were studied in chapter 3. Off-line assessment (i.e., of the product after task execution) of students' graphical summaries showed that a limited number of students was able to construct a graphical summary in a well-organized and hierarchically structured way. Also on-line data (i.e., of the process during task execution) were captured by means of the think-aloud methodology and a digital writing pen (i.e., duration of the writing phases, revisions made). The results indicated that students experienced great difficulties with thinking aloud during summarizing. Possibly, this is due to the additional cognitive demands related to the task difficulty or students' still underdeveloped verbalization skills to describe their cognitive operations during making a graphical summary. Pen movement analysis on the other hand was found to be very promising to gain insight into students' dynamic graphical summary construction process. This analysis revealed that only few students explicilty engaged in the metacognitive processes of planning and revising their graphical summary. Finally, also students' general achievement level was included in chapter 3 as a particular student-level characteristic. Students' general achievement level seemed not to be related to either strategy use, beloning to a specific repertoire group, or the quality of students' graphical summary products. Surprisingly, low-achievers did spend more time on pre-writing before grahpical summary construction.

Three considerations can be made when comparing the results obtained in chapter 2 and 3.

First, although the text-learning strategy protocol presented in chapter 3 was developed apart from the results obtained in chapter 2, important parallels can be drawn with the subscale categorization of the Text-Learning Strategies Inventory. As in the large-scale self-report study presented in chapter 2, the think-aloud protocols' main categories in chapter 3 are consistent with text-learning strategy categorizations related to their nature (e.g., cognitive and metacognitive) and perceptibiliy (i.e., overt or covert). Second, remarkably, in both empirical studies no motivational strategies during text learning were retained from the factor analysis (chapter 2) or identified in the think-aloud transcripts (chapter 3). This might be due to the rather unconsious presence of motivation without active regulative control (Wolters, Benzon, & Arroyo-Giner, 2011). Third, in both studies, students' strategy repertoire was profiled. To identify correspondence between this profiling, learner profiles identified in chapter 2 and strategy repertoires from chapter 3 are positioned on a 'width-dimension' and a 'depth-dimension'. These two important dimensions were originally described by the OECD (2010) to characterize students' reading process. Translated to our particular research context (i.e., investigating text-learning strategy use during informative text learning), the 'width-dimension' refers to the diversity of applied text-learning strategies (cf., x-axis in Figure 1) and the 'depth-dimension' refers to the level of depth, (cf., y-axis in Figure 1). Notwithstanding the different methodologies applied in both studies, parallels can be drawn between the identified learner profiles and strategy repertoires. In this respect, four main learner groups can be distinguished (Figure 1). A first group of learners posesses a basic level of text-learning strategies. They most frequently use one single text-learning strategy, mostly applied on a surface level (i.e., rereading, underlining). A second group already uses a more diverse text-learning strategy repertoire, mostly mental learning strategies, applied on a surface-level. Deep-level strategies are clearly missing in these two groups of learners. Learners in the third group already execute some strategies at a more deeper, generative level. However, their strategy use is still restricted to one or two frequently applied strategies and is not strategically integrated (i.e., they construct summaries but do not apply them for text learning). Group four represents learners with the most preferable profile, as they are strategic in their learning, and integrate various text-learning strategies.

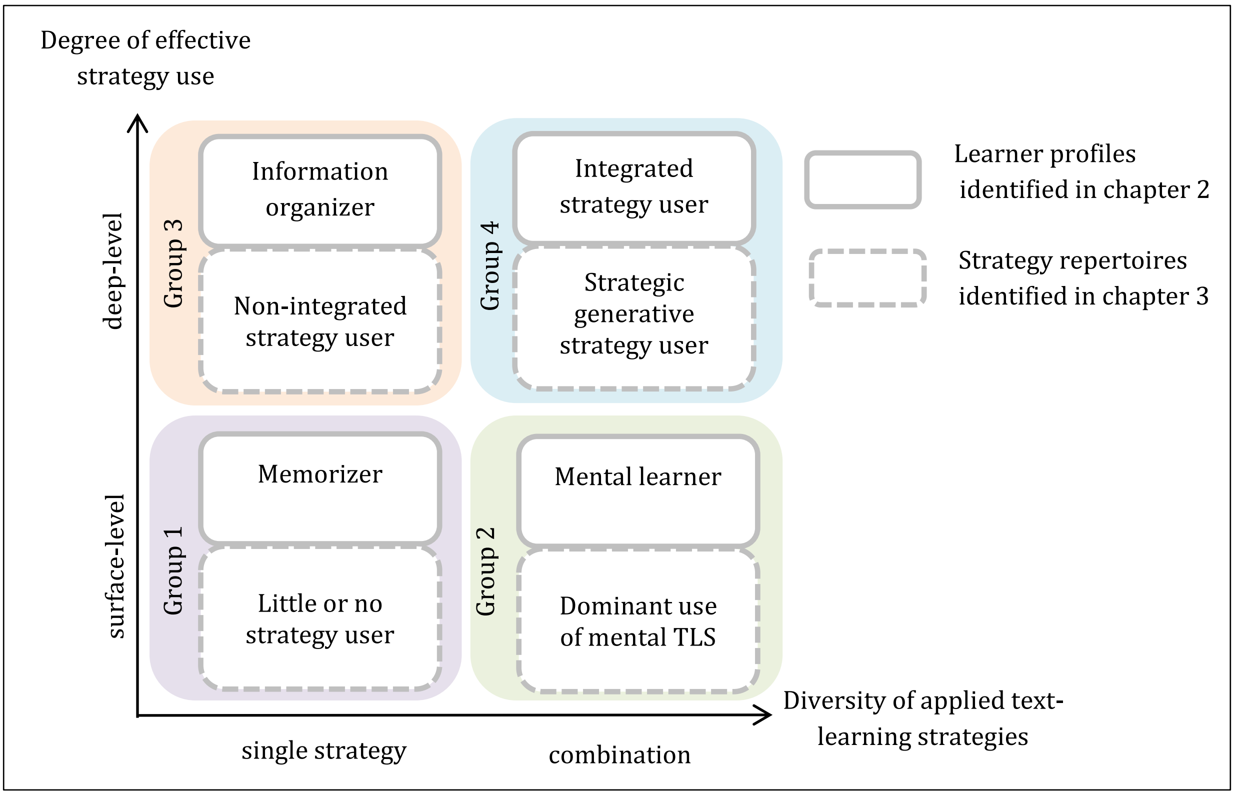


Figure 1. Correspondence between the profiles identified in chapter 2 and 3.

Both methods applied in chapter 2 and 3, respectively the self-report and think-aloud method, are associated with some advantages and disadvantages (see Table 1, Chapter 4). Especially the use of self-report measures has been criticized (Braten & Samuelstuen, 2007). Therefore the last study within the first research line, described in chapter 4, dealt with substantiating the validity of the TLSI, as it was intended to use this instrument in future large-scale research. By means of correlational analysis, the correspondence between students' self-reported (as reflected in the TLSI) and observed text-learning strategies (as reflected in their think-aloud transcripts) was verified. This comparison study mainly provided evidence for the validity of overt and covert cognitive strategy use (i.e., the TLSI subscales summarizing and schematizing, highlighting, rereading, paraphrasing, studying titles and pictures, linking with prior knowledge). On the other hand, examining the correlation between self-reported and observed metacognitive text-learning strategy use (i.e., the TLSI subscales planning, monitoring, and self-evaluation) was more difficult. Therefore, the interpretation of students' self-reported metacognitive text-learning strategies should be handled with caution.

To conclude, the main results of the studies included within the first research line can be summarized as follows.

As to *the assessment* of text-learning strategies in late elementary grades:

1. The developed measurement instruments (i.e., Text-Learning Strategies Inventory, Text-learning strategy protocol, and informative text- and scratch paper-rubrics) are validated research instruments that can be applied in future research to gather off-line product-oriented and on-line process-oriented data.
2. The results obtained by means of the developed measurement instruments underline the importance of orienting students towards learning from text and initiating text-learning strategy use already at the early stages of their schooling, as pre-adolescents only possess a very limited initial strategy base, with strategies applied rather superficially and not strategically.
3. Especially graphical summarization skills are still in their infancy.

As to *the profiling* of text-learning strategies in late elementary grades:

4. Different learner profiles or strategy repertoire groups can already be distinguished in late elementary education.
5. It is important to take into account both students 'depth' of strategy use and the 'width' or diversity of applied text-learning strategies.

Research line 2: Fostering generative text-learning strategies with a mind map strategy instruction

In a second research line, the effectiveness of a mind map strategy instruction intervention was examined in the light of the promising role of using graphic organizers to enhance learning from text (Nesbit & Adesope, 2006; Vekiri, 2002). Prior to the large-scale intervention, a pilot-study was conducted (chapter 5), verifying whether children aged 11 and 12 are already capable of constructing mind maps from an informative text. Robinson (1998) underlined in this respect that instruction should incorporate graphic organizers that are easily to be constructed by novices. To investigate this, a ten-week researcher-delivered strategy instruction was developed, wherein students gradually learned to construct mind maps from informative texts. 62 fifth and sixth graders took part in this pilot study, wherein a pretest, intermediate test, and posttest was administered (i.e., mind mapping an informative text) to analyze students' (a) progress in the application of mind map rules and (b) processing of textual information by means of mind mapping. Results from this study showed that 11- and 12-year olds are indeed able to learn to process informative texts by means of mind mapping, and underline the importance of a systematic and consequently stimulating environment to induce these skills. The developed strategy instruction served as a baseline in the further studies.

In the four subsequent chapters, mind mapping was investigated as an organizational learning strategy (chapter 6 and 7) and as a meta-learning strategy (chapter 8 and 9). Within these four chapters, the influence of the instructional approach (i.e., working with either researcher-provided or student-generated maps) and student characteristics (i.e., grade, gender, home language, general achievement level, and learner profile) was taken into account. In two experimental conditions, a teacher-delivered mind map strategy instruction was implemented, wherein either researcher-provided (RPMM) or student-generated mind maps (SGMM) were used. Also a control condition, receiving no mind map instruction, was included to provide an objective comparison baseline. Data for these studies were collected during a large-scale intervention study including 644 fifth and sixth graders (n_{RPMM}= 213, n_{SGMM}=219, n_{control}=212) from 17 different elementary schools. During a pretest, posttest, and retention test students completed a learning task and a graphical summarization task.

The studies described in chapter 6 and 7 concern the application of mind mapping as an organizational learning strategy. To this end, data from the graphical summarization task were analyzed as it was examined to what extent students' graphical summarization skills can be enhanced by means of a mind map strategy instruction. In the study described in chapter 6, detailed trace analyses were conducted on students' independently created graphical summary products. Multi-level piecewise growth analyses were used on various aspects of students' informative text traces, graphical design and graphical content, examining students' growth from pretest to posttest (phase 1) and from post- to retention test (phase 2). Results showed a significant growth and sustained effects for students' graphical summarization skills in favor of the experimental condition students. Greatest effects were found for students in the student-generated mind map condition. These students executed the strategic activities integrated in the graphical summarization strategy more autonomously in a goal-oriented way. They spent more careful attention to important pre-writing activities (i.e., text selection and organization in the informative text) and overall outperformed researcher-provided mind map condition students on the quality of the graphical design, and an important aspect of the graphical content (i.e., choosing relevant blanket terms). However, an important notification must be made in this respect. In the pilot-study (chapter 5), students were found to experience difficulties with including images and symbols into their mind map, aspects related to mental imagery processes beneficial for learning text (Anderson & Hide, 1971; Leopold, Sumfleth & Leutner, 2013). Remarkably, however, in particular students in the researcher-provided mind map condition showed a larger growth than students in the student-generated mind map condition in this respect. Gender and grade as student-level characteristics were found to be most strongly related to students' graphical summarization skills in this study. Surprisingly and in contrast with prior research (Hattie, Biggs, & Purdie, 1996; Nesbit & Adesope, 2006), no aptitude-by-treatment interactions were found and all students, irrespective of their gender, grade, home language, or achievement level, seemed to have profited equally from both strategy instructions.

The data capturing technique with the digital writing pen and pen movement analysis, explored in chapter 3, was integrated into the larger-scale intervention study and applied on a smaller subsample (n=18). The study described in chapter 7 represents therefore a sub-study of chapter 6, studying students' graphical summarization process in detail. Despite the significant growth in the quality of experimental condition students' products, no significantly different growth was observed between the three conditions regarding their regulatory processes guiding graphical summarization (i.e., time spent on pre- and post-writing activities). However, as to the detailed exploration of the construction phase itself, different approaches in the stepwise elaboration of graphical summaries could be distinguished. These elaboration approaches were shown to be related with the quality of students' final product. In this respect more effective (i.e., main idea elaboration, and successive branch elaboration) versus less effective elaboration approaches (i.e., linear sequential elaboration, inconsiderate elaboration, structured elaboration) could be identified. Remarkably, students from both experimental conditions largely followed a successive branch elaboration approach. Furthermore, different construction steps were detected by delimiting construction steps as 'fluent associations of key words and branches to each other'. Gaining insight into these elaboration approaches and construction steps is relevant, as it is important to take into account beginner difficulties when developing or adjusting strategy instruction (Hilbert & Renkl, 2008).

The studies described in chapter 8 and 9 concern the application of mind mapping as a meta-learning strategy. To this end, data from the learning task were analyzed in chapter 8 to verify to which extent the mind map strategy instruction induced a larger set of spontaneously used cognitive and metacognitive text-learning strategies. Here, students from the researcher-provided mind map condition showed the greatest gains and more sustained effects in the spontaneous application of overt deep-level cognitive strategy use during independent text learning. This was against expectations, as it was predicted that the more students are actively engaged and provided with explicit instruction in the strategy of making mind maps, the more strategy transfer would occur (Garner, 1990; Frazier, 1993; Kirstner et al., 2010). As to the metacognitive strategy use little to no significant changes were observed. However, as found in chapter 4, the results concerning students' self-reported metacognitive strategy use should be handled with caution. Furthermore, in line with results obtained in other studies (e.g., Frazier, 1993; Wade et al., 1990) no significant gains were found in free text recall in favor of the experimental condition students. In contrast, control condition students' free text recall significantly evolved from pre- to posttest. In chapter 8, four possible explanations were already provided for this finding (i.e., influence of the dual task students were focusing on, utilization deficiency, limited study time and Fuzzy Trace Theory). However, some additional explanations can be provided why no direct recall effects were observed in favor of the experimental conditions, despite their overt cognitive deeper-lever strategy use. First, from the perspective of writing-to-learn research, Bangert-Drowns, Hurley, and Wilkinson (2004) ascribe lower effects regarding 'writing to learn' for students in grade 6-8 to developmental issues. In this respect, subject matter becomes more distinctly differentiated at middle school level and the transition into new subject-specific writing forms may interfere with the writing-learning relationship. Second, Hübner, Nückles, and Renkl (2010) provide an overview of various reasons for deficiencies in strategy use, mentioning the mediation deficiency (i.e., students are not able to use a strategy to improve their performance since they do not possess the necessary cognitive requirements), the production deficiency (i.e., learners are capable to execute effective strategy use but do not apply these strategies spontaneously), and the already mentioned utilization deficiency (i.e., spontaneous strategy use does not increase recall) (Miller, 2000). As to the latter, Miller (2000) states that the available cognitive capacity is largely devoted to strategy application, leaving no capacity for text learning. Third, Wigfield, Klauda, and Cambria (2011) state that students will possibly be more engaged in effective regulatory strategies when they know an assignment has grade implications, but will be less inclined to do so just to learn something new. Fourth, Wade and colleagues (1990) state in their research at college level that, for the immediate recall of information, a number of strategies might be equally effective. This might possibly explain why control condition students did attain higher free recall scores, despite the fact that they were not significantly more engaged in overt deep-level strategy use.

In chapter 6, the role of student-level characteristics (i.e., gender, grade, home language, and general achievement level) was explicitly studied to verify the intervention's effectiveness regarding the promotion of graphical summarization skills. To this end, multilevel piecewise growth analyses were conducted, including interaction effects between the student characteristics, the experimental conditions, and the phases (from pretest to posttest and from posttest to retention test). Parallel analyses including these interaction effects were not included in chapter 8. However, also regarding students' text-learning strategy use it is interesting to explore similar interaction effects regarding students' growth in applying these strategies. Therefore, parallel analyses were conducted on the dependent variables studied in chapter 8, that is students' self-reported strategy use (i.e., the nine subscales of the Text-Learning Strategies Inventory), students' traced strategy use (i.e., informative text-score and scratch-paper score), and their free recall scores. Furthermore, also the influence of students' learner profile was investigated as an additional student-level characteristic. The initial learner profile of students involved in the intervention study was identified with a k-means cluster analysis in chapter 1. In what follows, the main and most important findings resulting from these analyses are described. In general, little to no significant interaction effects were found for home language and gender. Within the researcher-provided mind map condition, mainly effects of gender and learner profile are manifested. More particularly, girls attain significantly higher scores than boys as to their scratch-paper score from pretest to posttest (χ^2=4.101, df=1, p=.042). Mental learners' growth is significantly higher than the growth of memorizers as to their self-report on highlighting (χ^2=4.012, df=1, p=.045) and the quality of their informative text traces (χ^2=9.382, df=1, p=.002) from pretest to posttest. Within the student-generated conditions, mainly effects of students general achievement level are manifested. In this respect low-achievers, compared to average-achievers, report to have used significantly more strategies regarding linking with prior knowledge (χ^2=4.926, df=1, p=.026) and significantly less paraphrasing (χ^2=5.035, df=1, p=.025), and highlighting strategies (χ^2=6.106, df=1, p=.013) from posttest to retention test. However, as to the latter, this result could not be confirmed in the trace analysis of students' observed text-learning strategies on their scratch papers (χ^2=0.646, df=1, p=.422). High-achievers report to have applied significantly more rereading strategies (χ^2=13.562, df=1, p<.001) from pretest to posttest. Also interaction effects between the experimental conditions were verified, mainly confirming the general line of results, i.e., students in the researcher-provided mind map condition made the greatest progress as to the overt deep-level strategy use. However, as to students' learner profile, some important remarks can be made. First, memorizers attain a significantly higher informative text-score in the student-generated mind map condition from pretest to posttest (χ^2=4.378, df=1, p=.036). Second, integrated strategy users (χ^2=13.330, df=1, p<.001), mental learners (χ^2=8.306, df=1, p=.004), as well as memorizers (χ^2=5.881, df=1, p=.015) attain a significantly higher score regarding the quality of their scratch paper traces in the researcher-provided mind map condition from posttest to retention. For information organizers in both conditions, no significant differences could be revealed (χ^2=0.001, df=1, p=.975). Consequently, it appears that, with regard to the sustained enhancement of the quality of information organizers' scratch paper notes, it does not seem to matter in which experimental condition students are included.

In chapter 9 the final empirical study of this dissertation is presented. This study represents a sub-study of chapter 8 as spontaneous mind map users during independent text-learning are studied more in-depth. Also the relationship between spontaneous mind map construction and motivational variables (i.e., mind map-appreciation and mind map self-efficacy) was explored. Three important results emerged from the analyses. First, mind map users appreciate the technique more, and also judge themselves as more competent in creating mind maps. This underlines the importance of considering motivational aspects in learning, as children will only be likely to invoke effortful and time consuming strategies when they believe in the successfulness of their strategy (Garner, 1990). Second, spontaneous mind map users were predominantly girls and mainly students from the researcher-provided mind map condition. These groups also appreciated the technique more. Third, no significant difference in free text recall was found between students who did and did not construct a mind map during text studying.

To conclude, the main results of the studies included within the second research line can be summarized as follows.

As to the application of mind mapping as an *organizational strategy*:

1. Children aged 11 and 12 are already capable of independently constructing mind maps (applied as graphical summaries) from informative texts.

2. The largest gains were found for students in the student-generated mind map condition. They executed the strategic activities of the graphical summarization strategy more autonomously in a goal-oriented way.
3. Gender as a student-level characteristic was found to be most strongly related to students' graphical summarization skills in the researcher-provided mind map condition. For students in the student-generated mind map-condition, both gender and grade were found to be most strongly related to students' graphical summarization skills.
4. No aptitude-by-treatment interactions were found.
5. Small effects were found concerning the growth of experimental condition students' regulatory processes guide their graphical summary construction (pre-writing or planning and post-writing or revising).

As to the application of mind mapping as a *meta-learning strategy*:

6. The largest gains and sustained effects were found for students in the researcher-provided mind map condition with regard to overt cognitive deep-level strategy use.
7. Small to no significant effects were found as to experimental condition students' growth in metacognitive text-learning strategy use and free text recall.
8. Gender and learner profile as student-level characteristics were found to be most strongly related to students' text-learning strategy use in the researcher-provided mind map condition.
9. General achievement level differences were found to be most strongly related to students' text-learning strategy use in the student-generated mind map condition.
10. Students who spontaneously construct mind maps during text learning are predominantly girls and students from the researcher-provided mind maps condition. Spontaneous mind map users also appreciate the technique more and judge themselves as more competent in creating mind maps.

Limitations and suggestions for future research

Some limitations are inherently related to the studies presented in the different dissertation chapters. In each of the studies presented in chapter 2 to 9, specific study limitations are already addressed. These specific study limitations are summarized in the Appendix. In the following paragraphs, a general overview of the overall limitations of this dissertation is provided. More particularly, limitations related to the studied variables and methodological limitations are discussed more in-depth. However, the limitations are explicitly grasped to inspire future research. The map on the following page (Figure 2) provides an overview of the structure of the discussed limitations and suggestions for future research linked to the theories described in chapter 1 and 10.

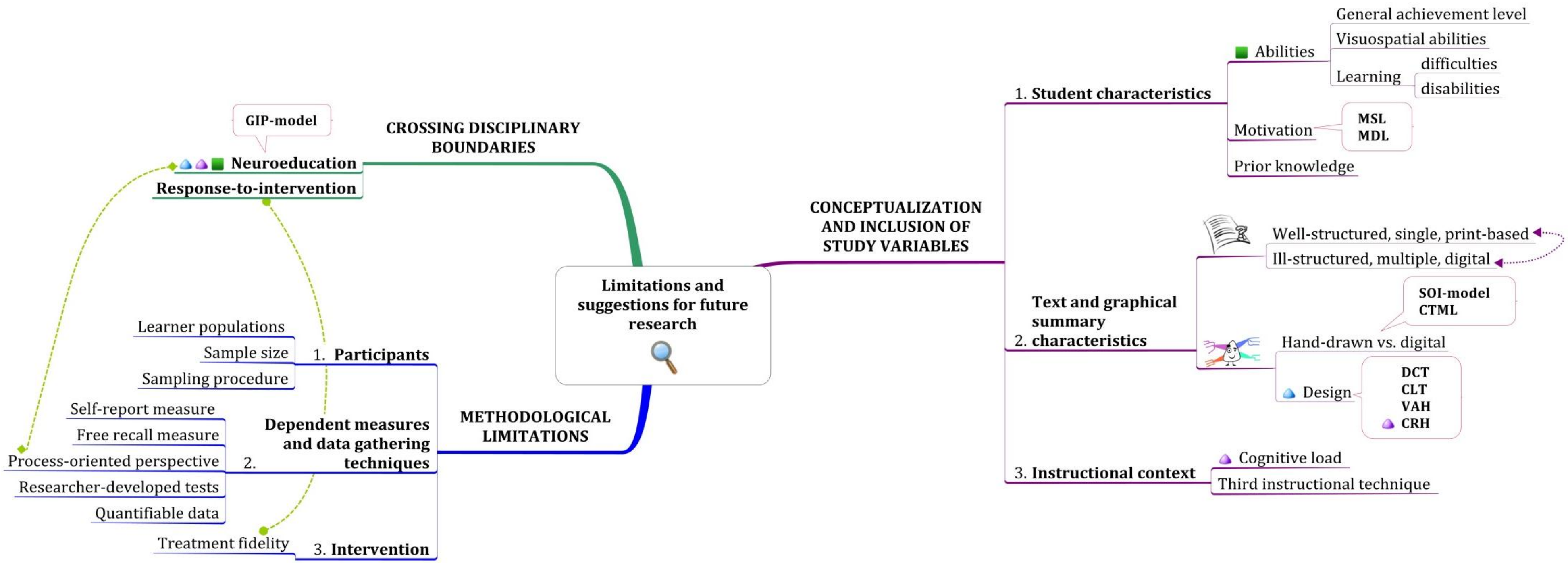


Figure 2. Overview of the structure of the discussed limitations and suggestions for future research.

Note. MSL = Model of Strategic Learning (Weinstein, Jung, & Acee, 2011), MDL = Model of Domain Learning (Alexander, 1998), SOI-model = Selection Organization Integration model (Mayer, 1996), CTML = Cognitive Theory of Multimedia Learning (Mayer, 2001), GIP-model = Good Information Processing model (Pressley et al., 1989), DCT = Dual-Coding Theory (Paivio, 1991), CLT = Cogntive Load Theory (Sweller & Chandler, 1994), VAH = Visual Argument Hypothesis (Waller, 1981), CRH = Conjoint Retention Hypothesis (Kulhavy et al., 1993).

Conceptualization and inclusion of study variables

Many factors contribute to success in learning from texts, including learner characteristics, characteristics of the text and the graphical summary, and factors related to the instructional context (Fox, 2009; McMaster, Espin, & van den Broek, 2014; RAND, 2002; Vekiri, 2002) (Figure 3). Limitations of the present dissertation and suggestions for future research are related to these three components (i.e., learner characteristics, characteristics of text and the graphical summary, and instructional context). These are subsequently discussed.

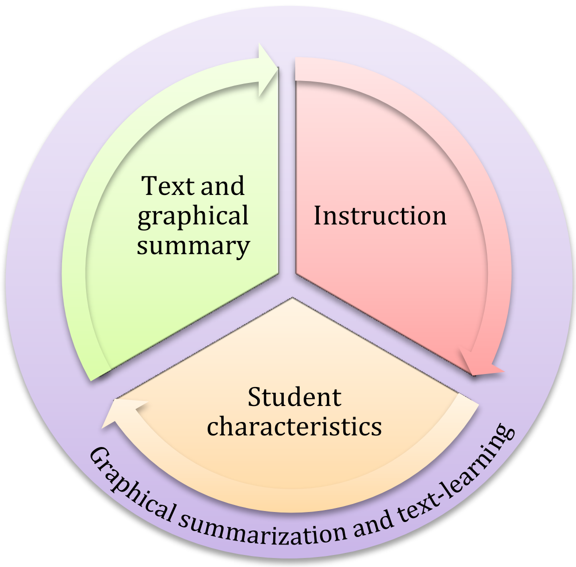


Figure 3. Relationship between the studied variables.

Student characteristics

A learner brings to the act of learning his/her specific abilities or capabilities, motivation, knowledge, and experiences (RAND, 2002). In this dissertation, the influence of these student characteristics has been explicitly studied. Concerning students' *abilities*, the influence of students' general achievement level (i.e., high, average, or low) was investigated in chapter 3 and 6. Additional to the analyses in chapter 8, these student characteristics were also included in the additional analyses referred to in the discussion section. The operationalization of students' classification into 'high-achievers', 'average-achievers', and 'low-achievers' can be considered as a first limitation, as this classification relied solely on teacher judgments. Even though experienced teachers can accurately judge students' general achievement level (Boekaerts, Pintrich & Zeidner, 2000; Desoete, 2008), and the distinction was corroborated by means of a researcher-designed text study test[2], future research should combine these teacher ratings with more objective measures of academic achievement to decide upon students' general ability level.

[2] The achievement-level distinction between 'high-achievers', 'average-achievers', and 'low-achievers' was corroborated on the pretest data of the large-scale intervention study (*n*=644), showing significant differences on free text recall between high achievers (*M*=21.29, *SD*=9.08), average achievers (*M*=16.51, *SD*=8.98), and low achievers (*M*=13.59, *SD*=6.57)(*F*(2, 618)= 36, 293, *p* < .001).

Further, students' general achievement level is related to learning from text in general (Carroll, 1993). However, students' visuospatial ability and visual-motor integration, which are abilities specifically related to learning from and with graphical displays, were not taken into account in this dissertation. Visuospatial ability can be described as the ability to mentally generate and transform images of objects and to reason using these imagery transformations (Carroll, 1993). Visual-motor integration refers to coordinating finger-hand movement and visual perception (Beery, Buktenica, & Beery, 2004). In this respect, working with spatial representations might be less beneficial for students' with low-spatial ability (Vekiri, 2002) and also visual-motor integration can affect students achievement (Sortor & Kulp, 2003). Therefore, future research could include for example 'The Benton Judgment of Line Orientation Test' (BJLOT) (measuring visuospatial judgment) (Qualls, Bliwise, & Stringer, 2000) and the revised Beery-Bubtenika Developmental Test (measuring visual-motor integration) (Beery et al., 2004) to operationalize these potentially relevant student characteristics. The administration of standardized tests regarding students' abilities would furthermore allow the identification of specific learner difficulties of disabilities, such as dyslexia, or developmental coordination disorder (DCD), for example, in order to take these student-level characteristics into account in future research. Prior research has already indicated in this respect that using graphic organizers is associated with beneficial reading comprehension outcomes for students with learning disabilities (Kim, Vaughn, Wanzek & Wei, 2004).

Next to students' ability, a second important learner characteristic is *students' motivation*. Motivational aspects in text-based learning are slightly touched upon in chapter 9, where mind map self-efficacy and mind map appreciation were studied and found to be related with students' spontaneous mind map use. However, all studies largely focus on the 'skill'- and 'self-regulation'-component of strategic learning (Weinstein et al., 2011), by studying students' cognitive and metacognitive text-learning strategy use. The third motivational-affective component 'will' (Weinstein et al., 2011) is underexposed in this dissertation. Future research should therefore include motivation-related variables, such as topic interest (Alexander et al., 1997; 2003; Clinton & van den Broeck, 2009; Fox, 2009), attributions, intrinsic motivation, and reading motivation, for example, as these appear to be important predictors of the adherence to effective strategies, the depth of text processing, and academic achievement (i.e., text comprehension and learning) (e.g., De Naeghel, Van Keer, Vansteenkiste, & Rosseel, 2012; Fox, 2009; Linnenbrink & Pintrich, 2002; Meneghetti, & De Beni, 2010; Taboada, Tonks, Wigfield, & Guthrie, 2009; Winne & Nesbit, 2009). Furthermore, future research could infuse motivational aspects (e.g., match informational texts to students' interest) into the mind map strategy instruction as the effectiveness of strategy interventions might be bolstered when developed in the light of theories emphasizing motivational aspects of self-regulated learning (Dignath & Büttner, 2008; Vaughn et al., 2013).

Student's (relevant) *prior knowledge* is a next important student characteristic in text learning research (Fox, 2009; McNamara & Kintsch, 1996). In this respect, a third limitation is related to the prior knowledge test administered before the learning task described in chapter 2, 3, and 8. Here, free-recall testing was applied to gain insight into students' prior knowledge of the text topic. However, in best cases, multiple forms of assessments should be used for a complete characterization of prior knowledge, as this might hinder or influence the learning process (Dochy, Segers, & Buehl, 1999). Therefore, future research should also consider other forms of prior knowledge tests, such as open questions, multiple choice tests, cloze tests, completion tests, and recognition tests, which also provide valid means of assessment (Dochy et al., 1999).

Text and graphical summary characteristics

Besides the limitations related to specific student characteristics, the following limitations relate to the applied texts and the graphical summary format of mind maps in this dissertation.

As to the texts, this dissertation focused on the use of text-learning strategies during the engagement with a generally *well-structured, single, print-based* informative text. Realizing that different results might have occurred with more ill-structured texts, future research should also take into account less-cohesive texts or should vary the organizational structure of texts (McNamara & Kintsch, 1996). Further, future research should also focus on strategically processing and learning multiple texts, taken into account the intertextual reality of our modern Western society wherein students increasingly learn about different topics from multiple sources (Braten & Stromso, 2011). In this respect, the Text-Learning Strategies Inventory (TLSI) developed in this dissertation could be compared with the Multiple-Text Strategy Inventory (Braten & Stromso, 2011), which is a 15-item self-report questionnaire assessing high school students' perceived text processing strategies when working with different texts. Moreover, in this digital age, students are increasingly confronted with new text presentation formats, such as digital texts, often including hypertext (i.e., links to other texts) and hypermedia (i.e., texts, graphics, videos). This provides new challenges to students' text comprehension and learning (Alexander & Res, 2012; RAND, 2002). In this respect, students were already found to approach print-based and digital texts differently (Liu, 2005; Kang, Wang, & Lin, 2009). Future research could also study text-learning strategies when working with digital texts.

As to the graphical summary, *hand-drawn graphical summaries* were used in the research-provided mind map condition, and students were taught to draw by hand in the student-generated mind map condition. In line with the abovementioned suggestions regarding digital texts, it would be very interesting to investigate how generative text-learning strategies can be fostered by means of a mind map strategy instruction enriched with multimedia in a digital learning environment (e.g., by means of digital mind mapping tools; Kim & Kim, 2012; Willis & Miertschin, 2006). The development of this digital environment can be inspired by Mayer's 'Selection Organization Integration (SOI) model' (Mayer, 1996) and his 'Cognitive Theory of Multimedia Learning (CTML)' (Mayer, 2001). A next limitation relates to the graphical summary's design characteristics in this dissertation (i.e., using colors, dimension, images, radial structure). Although the effectiveness of including these aspects into the graphical design was already demonstrated (e.g., Wallace, West, Ware, & Dansereau, 1998; Leopold et al., 2013), it would be worthwhile to corroborate the effectiveness of the specific mind map design-principles in future research. Mind map research in more experimental settings could reinvestigate the hypothesis positioned in the theoretical frameworks of the Dual Coding Theory (Paivio, 1991), Cognitive Load theory (Sweller & Chandler, 1994), Visual Argument Hypothesis (Waller, 1981), and Conjoint Retention Hypothesis (Kulhavy, Stock, Woodard, Haygood, 1993), and could cross-fertilize classroom-based investigations in this respect (e.g., letting students study a colored and uncolored mind map and compare their performance).

Instructional context

In addition to the abovementioned limitations related to student, text, and the graphical summary characteristics, two concrete limitations regarding the intervention study's instructional context are addressed. In the light of the Cognitive Load theory, as already mentioned in chapter 1, students' learning in class could be hampered by extraneous *cognitive load*, related to the instructional design (Sweller & Chander, 1994; Sweller, van Merriënboer, & Paas, 1998). In this dissertation, no insight was provided into students' cognitive load during the implementation of the mind map lessons. However, it could be hypothesized that students in the researcher-provided mind map condition might have experienced less extraneous cognitive load through their interaction with worked-examples (Paas, Tuovinen, Tabbers, & Gerven, 2003; Schwamborn, Thillmann, Opfermann, & Leutner, 2011). In turn, this could possibly explain why higher gains for these students were found in their spontaneous application of deeper-level text-learning strategies during independent text learning (chapter 8 and 9). Future research is encouraged to verify this hypothesis. Students' perceived cognitive load could be measured with the Cognitive Load rating scale (Paas, 1992; Paas et al., 2003), wherein students rate how much effort it took them to execute a certain task. de Jong (2010) furthermore argues to develop new cognitive load measures discerning intrinsic, germane, and extraneous cognitive load, on which attempts have already been made (e.g., Leppink, Paas, Van der Vleuten, Van Gog, & Van Merriënboer, 2013).

Further, during the mind map intervention described in chapter 6 to 9, teachers applied the instructional techniques of either working with researcher-provided mind maps ('learning by viewing'; Stull & Mayer, 2007) or student-generated mind maps ('learning by doing'; Stull & Mayer, 2007). However, a number of studies point at the effectiveness of *a third instructional technique*, that is the gradual fading of worked-out steps to foster learning and near transfer (e.g., Atkinson, Renkl, & Merrill, 2003; Renkl, Atkinson, & Maier, 2002). More particularly, students are provided with much support and worked-examples in the beginning of the learning period and less support when they progress in skill acquisition (e.g., Atkinson et al., 2003; Renkl et al., 2002). This instructional technique is developed in view of the expertise-reversal effect, stating that more experienced learners might no longer benefit from fully guided instruction with worked-examples (Kalyuga, Ayres, Chandler, & Sweller, 2003). It would be interesting to investigate the effects of a mind map intervention permeated with this third instructional technique. Here, teachers could work with researcher-provided maps (i.e., worked-examples) during the first part of the intervention period and the solution steps could be gradually faded out while students learn to construct their own mind maps. With an eye on follow-up research, such a mind map strategy instruction program was developed and implemented into authentic classes, and data-collection was finalized. Data will be analyzed in the near future, and the results found for the three instructional techniques will be compared.

Methodological limitations

In what follows, methodological limitations are addressed, which are related to the participants, the dependent measures and data gathering techniques, and the intervention.

Participants

All studies included in the dissertation relate to late elementary school students from middle-class schools, of which the vast majority had Dutch as their home language. In this respect, some questions might arise regarding the generalizability of the obtained results to older (i.e., secondary or higher education students) and more diverse (i.e., students with a different nationality) *learner populations*. Therefore, it is advised to substantiate the ecological validity of the obtained research findings by increasing the number of school-based intervention studies in secondary and higher education, including also more diverse learning populations to establish national and international comparative research.

A second concern regarding the generalizability of the results relates to the *small sample sizes*, included in the studies reported in chapter 3, 4, and 7. These are associated with the intensity of the think-aloud data gathering technique on the one hand (i.e., chapter 3 and 4), and the applied digital media (i.e., digital writing pens) on the other hand (chapter 7). The small sample sizes compromise the degree to which the results can be generalized, as they do not reflect representative variability in the study sample. Therefore, future research is encouraged to corroborate our obtained results in larger-scale research. In this respect, the smaller-scale sub-study described in chapter 7 can for example be seen as a pilot study of the in-depth and theoretically led process examination of the construction of graphical summaries.

A third concern relates to *the sampling procedure* of the participants involved in the intervention study. In this respect, a call for participation in the 'mind map-project' was launched in the beginning of May 2011, addressing fifth- and sixth-grade teachers and principals from various elementary schools in many ways (i.e., personalized information letters, emails, information brochures, website information, phone calls). Elementary schools could subscribe to a school visit to receive more detailed project information and interested schools were visited in this respect. Schools were randomly assigned to the treatment conditions after agreeing to participate. As a result, all schools included in the large-scale intervention study were aware of the general project aims and treatment conditions. Therefore, it might be possible that the intervention's appeal evoked that some control condition teachers adopted strategies that were targeted in the intervention group. This is a commonly occurring phenomenon in school-based intervention research as keeping control groups teachers blind to treatment distinctions is a seemingly intractable problem in educational research (Boekaerts & Corno, 2005). Although the training in the experimental conditions ensured a firewall between the treatment and control group, future research might invest in conducting classroom observations, to determine the extent to which there is overlap between treatment and comparison conditions (Vaughn et al., 2013).

Dependent measures and data gathering techniques

A first concern relates to the applied *self-report measure,* i.e., the Text-Learning Strategies Inventory. In line with our specific aim to develop instruments to assess text-learning strategy use oriented towards students in the age 11-12, the validated instruments in this dissertation (i.e., Text-Learning Strategies Inventory, and also the Think-aloud protocol, informative text- and scratch-paper rubrics, Mind Map Scoring Rubric) are specifically tailored to our study sample, that is late elementary education students. Possibly, these measurement instruments might need modifications when applied in studies addressing the text-learning strategy use of older age groups. Furthermore, the investigated self-reported text-learning strategies were limited to the content of the inventory. Students had to rate prelisted inventory items, although they might have used other strategies during learning as well. As a result, some other potentially relevant aspects or strategies in text-learning were not assessed. Future research could therefore focus on validating the TLSI in further research and could consider adding new items to the TLSI if found necessary (Braten & Stromso, 2011).

A second concern relates to the applied *free recall measures* to assess students' learning performance after studying an informative text (chapter 2, 8 and 9). The studies included in this dissertation have largely focused on the process function of graphic organizers, that is, the impact of graphic organizers as thinking procedures to assist learners on steps to carry out a cognitive operation (Ponce & Mayer, 2014). In this respect, the most important dependent variables where students' graphical summarization skills and independently used text-learning strategies, as these reflect strategies assisting students in learning from texts. However, less attention was paid to the product function of graphic organizers, that is, the impact of studying with graphic organizers on learning outcomes (Ponce & Mayer, 2014). The applied free recall measures to asses students' learning outcomes in this respect was indeed rather straightforward. Future research should include a more comprehensive range of tests to obtain a clear and differentiated view of students' text comprehension and learning and assess multiple levels of understanding (McNamara, 2011) (e.g., students' construction of a coherent mental model of the text; Kintsch & van Dijk, 1978; McNamara, Ozuru, Best, & O'Reilly, 2007). In this respect, different response formats can be used, such as cued recall tests, recognition tests, transfer tests, or delayed recall test (McNamara, 2011). An additional important aspect to be considered in this respect is students' strategy adoption, which might differ according to students' test expectations (Broekkamp & Van Hout-Wolters, 2007; Samuelstuen & Braten, 2007). In our studies, students were aware that they would receive a test after studying but they did not receive any additional and particular test specifications. Especially at post- and retention test, strategy adoption might have played a role in their strategy use, as they could assume a free recall test would be administered again. Future research should systematically explore factors influencing students' strategy adoption (e.g., specific task demands) (Broekkamp & Van Hout-Wolters, 2007) and relate this to their actual learning performance.

A next limitation relates to the data that were gathered from *a process-oriented perspective* (i.e., on-line measures such as the think-aloud data and pen movement data). Although meaningful insights were derived from data that emerged from these analyses, the use of on-line measures was limited. Future research could therefore explore the use of technology in gathering process-oriented data with minimal intrusion, for example by collecting software logged data or applying eye-tracking methodology (e.g., Ariasi & Mason, 2011; Hadwin, Nesbit, Jamieson-Noel, Code, & Winne, 2007; Hyöna, Lorch & Rinck, 2003; Ponce & Mayer, 2014; Scheiter & van Gog, 2009; Winne & Jamieson-Noel, 2002). For instance, in contrast with the investigation of students' static traces left behind after task execution in this dissertation, students' log file traces (i.e., sequences of study actions) can be registered by means of software, registering time-stamped records of everything a student does within in a particular (digital) learning environment (Hadwin et al., 2007; Malmberg, Järvelä, & Kirschner, 2013). Furthermore, by means of eye-tracking, students' eye position can be registered while moving through visual stimuli (e.g., texts and graphical displays) (Scheiter & van Gog, 2009). Eye-tracking can provide meaningful insights in students' text processes occurring rather quickly or automatically (Scheiter & van Gog, 2009), as the direction of human gaze is closely linked to students' attention during information processing (eye-mind hypothesis; Just & Carpenter, 1980) This methodology has already been applied in research on learning from expository texts (e.g., Ponce & Mayer, 2014; Scheiter & Eitel, 2010). For example, Ponce and Mayer (2014) studied university students' use of a linear or generative learning strategy by tracking their saccades (short eye movements) during learning texts with either taking notes or working with graphic organizers. In this respect, integrative saccades (i.e., up-down saccades between the top and bottom of the page) and constructive saccades (i.e., left-right saccades between text and graphic organizer) indicated generative learning strategy use. Working with graphic organizers was more likely to prime a generative learning strategy. Similar research in the context of learning informative texts with mind maps could be very interesting and enlightening. Data triangulation remains a prerequisite, however, as logfile traces and eye-tracking data are not always straightforward interpretable (Malmberg et al., 2013).

A following test-related constraint is the fact that all tests included in the different studies were *researcher-developed*. Although these newly developed instruments allowed us to better capture the specific outcomes of the intervention (Boekaerts & Corno, 2005), which might have been overlooked when decontextualized instruments were used (Donker et al., 2014), future assessment packages should also include intervention independent tests. This might reduce the chance that trainers are tempted to direct students' performance to the used tests after the intervention (Donker et al., 2014). However, it must be noticed that standardized measures assessing learning from lengthy informative texts seem to be generally lacking in contrast with standardized reading comprehension measures, largely including only narrative texts.

A final limitation concerning the data gathering techniques is that the present dissertation was largely dominated by collecting *quantifiable data*, which were analyzed statistically in an objective manner (Creswell, 2008). Although also qualitative data gathering techniques were explored in chapter 3 and 7 (i.e., think-aloud methodology, collection of pen movement data), the use of qualitative data in this dissertation was limited. However, as the use of mixed method research is more and more encouraged in educational research, future research should strive to collect, analyze, and interpret both qualitative and quantitative data (e.g., by means of case studies, interviews, video observations) in a single study or a series of studies (Leech & Onwuegbuzie, 2009) and corroborate the obtained dissertation results.

Intervention

As to the large-scale intervention study, which results are reported in chapter 6 to 9, three concrete methods were applied to ensure *fidelity to treatment* (i.e., completion of structured protocol booklets, encouragement of lesson implementation and protocol completion, and a questionnaire administered after the intervention). However, little information is available on some 'unidentified features of instruction', such as time spent on covering course content in conventional ways (Bangert-Drowns et al., 2004), teachers' teaching style, and their own specific competences required for successful implementation (Smith, Daunac, & Taylor, 2007). Although a metacurricular approach is advised in literature (Boekaerts & Corno, 2005; Cornford, 2002), teachers may still find it difficult to balance the teaching of learning strategies on the one hand and the teaching of course content on the other hand (Vaughn et al., 2013). Additionally, there are substantial differences among teachers in their ability to produce achievement gains in their students (Nye, Konstantopoulos, & Hedges, 2004). It is furthermore important to verify whether the treatment providers (i.e., teachers) are able to deliver the intervention as designed (Smith, et al., 2007). For example, teachers in the student-generated mind map condition might have possessed low graphical summarization skills themselves, which could have hampered the successful implementation of this specific mind map strategy instruction. In this respect, future research should supplement the already used treatment fidelity measures with additional measures, such as systematic classroom visits, in-class support (where the researcher provides modeling, co-teaching, or observations with feedback), or planning sessions (where negotiable and non-negotiable portions of the intervention are clarified and assistance is provided for balancing content coverage and intervention requirements) (Smith et al., 2007; Vaughn et al., 2013). Further, additional tests might be assessed to map teachers' specific competences for successful intervention implementation (i.e., their own graphical summarization skills, awareness of different text-learning strategies) (Smith et al., 2007).

Crossing disciplinary boundaries

Tackling some of the above mentioned limitations might require crossing the traditional disciplinary boundaries (Hook & Farah, 2013). In this respect, interdisciplinary research is needed, wherein researchers from different disciplines collaborate to produce new knowledge by bi-directional and reciprocal interactions (van Rijnsoever & Hessels, 2011). Educational neuroscience of '*neuroeducation'* is an example of such an interdisciplinary research. In this emerging scientific field, the disciplines of neuroscience, psychology, and education are linked to improve learning and instruction (Ansari, De Smedt & Grabner, 2012). By means of neuroimaging methods such as fMRI (i.e., functional Magnetic Resonance Imaging), EEG (Electroencephalography), and MEG (magnetoencephalography), (magnetic) brain activity during the execution of school-taught skills can be mapped. This could provide meaningful detailed insights into learning-related cognitive (sub)processes and working memory capacity (Ansari et al., 2012). Also Pressley Borkowski, & Schneider (1989) describe good neurology as the basis for good information processing in their good information processor model. For example, neuroscientific techniques might help identify new ways to measure cognitive load (de Jong, 2010), and can help in designing educational interventions by unraveling typical academic skills and provide multidimensional insights into specific learning difficulties (Ansari et al., 2012). Neurological brain research could also provide insights in the function of specific mind map design-principles (e.g., gestalt principles, mental imagery, radial structure).

Also *response-to-intervention (RTI) studies* are characterized by the employment of interdisciplinary teams (Vaughn et al., 2010). This differentiated intervention research focusses on non-responders of interventions. Based on interdisciplinary deliberation, these students are provided with subsequent systematic assistance, progress monitoring, and adjusted instructional interventions until they make sufficient progress. The international educational research community increasingly steers towards conducting such intervention research and it would be insightful to apply the RTI-design to the developed mind map intervention studies in this dissertation.

Implications of the dissertation

Implications for theory and empirical research

> "Educational interventions could probable be better captured with diverse theorizing and multiple methods" (Pressley, Graham, & Harris, 2006, p 12).

The studies included in this dissertation are enriched by diverse theoretical insights from different, but related research areas, such as self-regulated learning (e.g., Pintrich, 2004), general strategy research (e.g., Alexander, 1998; Mayer, 1996; Pressley et al., 1990; Weinstein et al., 2011), research in summarization instruction, reading-and-writing to-learn instruction (e.g., Mateos, Martin, Villalon, & Luna, 2008; Westby, Culatta, Lawrence, & Hall-Kenyon, 2010), and graphic organizers research (e.g., Nesbit & Adesope, 2006; Vekiri, 2002). In turn, this dissertation also contributes to these theories and their related empirical base in some important ways. Researchers from different theoretical orientations or rooted in different educational research fields (e.g., educational measurement, instructional design) can therefore take advantage of the proposed studies and results.

First, this dissertation resulted in newly developed instruments to assess and profile text-learning strategy use in late elementary education. Instruments for this specific target group and learning context were currently lacking in the research literature. More particularly, self-reports, study trace and graphical summary scoring-rubrics, and a think-aloud protocol (TAP) coding instrument were developed. These instruments are based on existing theoretical models of self-regulated learning (e.g., Pintrich, 2004) and learning strategy research (e.g., GSU-model, Pressley et al., 1990; SOI-model, Mayer, 1996; MDL-model, Alexander, 1998; MSL-model, Weinstein et al., 2011) and largely corroborate their proposed text-learning strategy categorizations (i.e., according to their nature, level or depth, perceptibility, and learning phase wherein the strategies are applied). These instruments were developed and integrated into different methodological designs (i.e., cross-sectional designs in chapter 2, 3 and 4, a repeated measures design in chapter 5, and a quasi-experimental repeated measures design in chapter 6 to 9). As a result, particular instruments have been validated in a first sample and cross-validated in a second independent sample. For example, the Text-Learning Strategies Inventory (TLSI) (chapter 2) was additionally validated on pretest data of chapter 8. Also, the Mind Map Scoring Rubric (MMSR) was developed in a pilot-study (chapter 5) and cross-validated in a large-scale study described in chapter 6. The interrater reliability of the scoring rubrics and the TAP coding instruments was high. Hence, this dissertation resulted in concrete measurement instruments, initially lacking in literature. The instruments furthermore allow to draw parallels between the obtained empirical results and theoretical models. More particularly, it was demonstrated in this dissertation that the instruments provide means for researchers to gain insight into students' (growth) in text-learning strategy use. Additionally, this strategy use can be profiled by means of the TLSI- and TAP-data, something not studied yet in younger age groups. Confirming the theoretical GSU-model (Pressley et al., 1990), describing young children's limited strategy knowledge and tendencies, the obtained results in chapter 2 and 3 also illustrate late elementary students' rather limited initial strategy repertoire. In this respect, the largest group of learners at the end of elementary education would therefore be characterized as acclimated learners in Alexander's Model of Domain Learning (Alexander, 1998).

Second, in response to the unfortunate decline in published high-quality intervention research (Hsieh et al., 2005) and the focus in foregoing research on rather short-term simple interventions instead of on longer and more complex interventions (Pressley et al., 2006), this dissertation invested in conducting a long-term intervention study. Herein, specific mind map strategy instructions were implemented. These strategy instructions have a well-founded theoretical base. In this respect, the instructional techniques applied in the strategy instruction adhered to stimulating essential cognitive processes of text selection, organization and integration, proposed in Mayer's 'Selection Organization Integration (SOI)'-model (Mayer, 1996). These essential processes were integrated into crucial phases of graphical summarization in particular (i.e., pre-writing, construction and post-writing; Berninger, Fuller & Whitacker, 1996; Flower & Hayes, 1981) and self-regulated learning in general (i.e., forethought, performance and reflection; Pintrich, 2000). Based on these theoretical insights, the strategy instructions extend the existing summarization literature since a comprehensive mind map strategy instruction for late elementary students was not yet forehand. Mind maps were deliberately incorporated into this strategy instruction, as their empirical investigation is under addressed in graphic organizer research. Their use was not limited to an organizational learning strategy, as also their value as a meta-learning strategy was explored. In this respect, the obtained results in this dissertation corroborate and extend previous research showing that also graphical summarization instruction can effectively induce deep-level generative strategy use (e.g., Westby et al., 2010). Furthermore and very importantly, also transfer of overt generative strategy use to independent text learning was revealed. This illustrates that the strategy instruction can help learners to progress in their evolution towards more competent learners, already using more efficient and effective strategies (cf. Model of Domain Learning, Alexander, 1998). In this way, this dissertation can lead to a continued renewed interest in mapping methods as meta-learning strategy to induce a larger repertoire of text-learning strategies.

In particular, further investigation is requested to unravel the relationship between the mind map strategy instruction and students' independent metacognitive text-learning strategy use. It is therefore hoped that researchers build on the conducted mind map research and are encouraged to engage in similar school-based intervention studies. In this respect, researchers could be inspired by some crucial general aspects that were taken into account in the intervention studies developed in this dissertation (chapter 5 to 9). First, complete naturally constituted classes and schools were assigned to the treatment and comparison conditions, leaving students' class composition unchanged. Quasi-experimental designs are very useful in this respect, as the random assignment of individuals to particular conditions is rather impossible, unpractical, or unethical (Weathington, Cunningham, & Pittenger, 2010) and the research in contextualized and implemented in realistic school settings in this way, reflecting typical learning environments. This makes the obtained results more generalizable (Linnenbrink & Pintrich, 2002). Treatment fidelity measures were implemented within this research design to verify intervention implementation. Second, the application of multilevel piecewise growth modeling in chapter 6 and 8 has taken into account the hierarchical nesting of students in classes and has contributed to the scientifically credibility of the obtained results. By opting for this design (i.e., quasi-experimental) and data analysis technique, it is more likely that the intervention outcomes can be traced directly to the intervention rather than to other extraneous (or confounding) factors (Hsieh et al., 2005). Third, the developed intervention studies also adhered to important components of high quality educational intervention research as (a) children were included into the interventions instead of adults, (b) intervention effects were also measured after a more extended period of time (cf. retention test), (c) treatment integrity was assessed, and (d) multiple outcome measures were combined (Pressley & Harris, 1994, Hsieh et al., 2005). Researcher are incited to invest in similar intervention research and to go beyond by undertaking interdisciplinary mixed-method research, as described in the limitation section of this dissertation.

Implications for practice and policy

As to the implications for practice, studies included within the first research line demonstrated students' limited initial text-learning strategy base and their rather non-strategic superficial application of text-learning strategies, including graphical summarization skills. These results underlined the need for the explicit teaching of text-learning strategies. A first step in initiating effective text-learning strategy use is gaining insight into students' initial strategy base. Therefore, the developed instruments, which are user-friendly in practice, provide a means for teachers to gain insight into students' text-learning strategy use and keep track on their evolution throughout the school year. By means of students' self-reports in the Text-Learning Strategies Inventory and the analysis of their study traces (i.e., in their texts and scratch papers), teachers can map students' depth of strategy use and the diversity of applied text-learning strategies. Teachers can furthermore use their collected information to gain insight into students' initial leaner profile, or in the way in which students already strategically combine different text-learning strategies. Additionally, in view of the particular importance of initiating graphical summarization, teachers can apply the developed Mind Map Scoring Rubric (MMSR) in daily practice. The MMSR is complemented with an accessible example-illustrated manual and can be used to assess and steer students' ability to create an effective graphical design and a coherent graphical content when summarizing informative text information. This dissertation furthermore points at the promising role of digital pens to assess students' dynamic graphical summarization process. By verifying students' pen movements, teachers and teachers coaching students with special educational needs can obtain a detailed picture on students' summarization skills, which can lead to intensive and adapted coaching.

The developed mind map strategy instruction furthermore provides a means for teachers in practice to incorporate learning-to-learn activities into their content courses to stimulate students' text-learning strategies and graphical summarization skills. The mind map strategy instruction using student-generated mind maps resulted in the largest effects on students' graphical design (chapter 6). However, the overall graphical summarization skills of students in the researcher-provided mind map condition also improved significantly as opposed to the control condition students. Furthermore no significant differences were shown in the quality of experimental condition students' graphical content. The ultimate goal of strategy instruction however is stimulating students' spontaneous application of effective text-learning strategies. In this respect, the mind map strategy instruction incorporating researcher-provided mind maps was most effective in stimulating students' overt deep-level strategy use and led to the most sustained long-term effects (chapter 8). Therefore, teachers are especially encouraged to implement the developed strategy instruction with researcher-provided mind maps into their content courses, by means of the developed instructional materials (i.e., course materials including student learning booklets incorporating ten mind map lessons, teacher manuals, and classroom posters). Furthermore, they can apply the developed tested step-by-step plan to other informative texts than the ones included into the developed course materials, as this was easily grasped by the teachers involved in the intervention studies. In this respect, four concrete sequentially to-be-followed steps are defined to process informative text information, i.e., (1) scanning the text, reading the text and clarifying incomprehension ('getting an overview') (2) identifying key information by highlighting relevant key words, subideas and supporting details in different colors ('text-organization strategy'), (3) active manipulation of the text material by means of mind map assignments ('text transformation-strategy'), and (4) reviewing the process and product outcomes. Students strategic activities can be supported during these lessons by a bookmarker visualizing and briefly summarizing these steps (Figure 4), as was applied in the large-scale intervention study. These four strategy components can furthermore serve as a sort of learning protocol to scaffold cognitive and metacognitive text-learning strategy use in other subject areas.

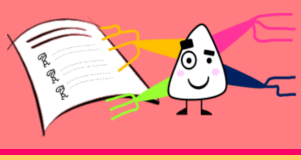
Scan and read the text, clarify incomprehension 	⋆ **I scan the text**  ⋆ **I read the text** ⋆ **Do I understand**  ⋆ words- content- other things?
Find key words and structure 	⋆ **I search for main ideas** ⋆ **I search for sub ideas connecting to my main ideas** ◆ 5W-H questions! (Who? What? Where? Why? When? How?) ◆ Often nouns – verbs ⋆ **I mark or underline**
Complete the mind map assignment 	⋆ **I use my text and mind map to complete the assignments**
Review your process and product 	**Did I follow all steps?** **Is my assignment correct and complete?** **Do I understand everything?**

Figure 4. Bookmark supporting students' strategic actions during mind map strategy instruction.

Further, some additional advice can be formulated towards practice to ensure the effectiveness of the mind map strategy instruction. First, it is essential to incorporate the strategy instruction in a systematic way over a sufficiently long period of time. Second, the training should be incorporated into students' daily lesson periods during content area courses. Third, systematically applying the step-by-step plan, and providing students with modeling, explicit instruction, and sufficient practice opportunities are important elements of the instruction. Fourth, next to dedicating explicit attention to the final mind map assignment solutions (product assessment), engaging in explicitly reviewing students' process of strategy application is equally important. An important precondition, however, to realize an effective strategy instruction is an extensive teacher training. Therefore, the developed teacher training in the intervention studies can serve as an example for the professional development of teachers at pre-service and in-service level. This will be a critical factor in ensuring that the mind map strategy instruction can be incorporated effectively. Furthermore, the training should be extended with learning teachers how to created powerful worked-example mind maps from informative texts themselves. Also school principals are encouraged to support teachers in implementing this strategy instruction, by providing them with the necessary training and in-class support, which will once again contribute to the professional development of the staff.

Finally, educational policy is steered to provide investments in interdisciplinary research programs such as neuroeducation for example to solve the remaining questions in this dissertation. Furthermore, they are encouraged to reinvigorate long-term educational intervention research, including response-to-intervention studies, by providing financial support and create opportunities for interdisciplinary training of researchers and teachers.

Final conclusion

Two important considerations drawn from self-regulated learning and text-learning strategy research (i.e., 'effective learners are strategic learners' and 'educational interventions should introduce learners in strategic learning') led to two important research lines handled in this dissertation. Three empirical studies reported in chapter 2, 3, and 4 fit in with the first research line 'assessing and profiling text-learning strategy use in late elementary education'. The empirical studies reported in chapter 5 to 9 fit in with the second research line, that is 'fostering generative text-learning strategy use by means of a mind map strategy instruction'. Within this second research line, the influence of different instructional approaches (i.e., working with either researcher-provided or student-generated mind maps) and student characteristics (i.e., gender, grade, home language, general achievement level, and learner profile) was studied. The chapters are characterized by methodological data-triangulation.

Regarding the first research line, this dissertation underlines the importance of mapping late elementary school students spontaneously used text-learning strategies during independent text learning, their initial learner profiles or strategy repertoires, and graphical summarization skills.

To assess and profile students' strategies in this respect, different instruments were explored, developed and validated (i.e., Text-Learning Strategies Inventory, Think-aloud learning strategy protocol, rubrics to score the quality of students' study traces, the Mind Map Scoring Rubric, analysis of pen movement data).

Regarding the second research line, two effective teacher-delivered mind map strategy instructions were developed (either incorporating researcher-provided mind maps or student-generated mind maps) which positively affected students' spontaneously applied overt cognitive deep-level strategies in general and graphical summarization skills in particular. Within these instructional approaches, gender as a particular student-level characteristic was overall most strongly related to students' text-learning strategy use. When aiming at optimizing students' graphical summarization skills, working with student-generated mind maps is advised. However, overall, the strategy instruction including researcher-provided mind maps resulted in the largest and most sustained effects as to students' applied strategies during independent text learning. Hence, the developed mind map strategy instruction, especially the one incorporating researcher-provided mind maps, provide teachers with an effective and powerful means to stimulate and foster generative text-learning strategy use (i.e., overt cognitive deep-level strategy use).

It is believed that the limitations related to this dissertation provide fruitful avenues for future research. Researchers are encouraged to engage in studies regarding student characteristics, characteristics of the text and graphical design, the instructional context and the proposed methodological considerations. Further, it is hoped that practitioners are inspired by the studies in this dissertation and encouraged to strategically implement mind mapping into their daily educational practices.

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Appendix

Main results, limitations and suggestions for future research, and implications of the studies linked to the research lines and dissertation chapters

Chapter	Main results	Limitations and suggestions for future research	Implications
RL 1: Assesing and profiling text-learning strategies			
2	- The developed self-report measure 'Text-Learning Strategies Inventory' is a valid and reliable measurement instrument to gain insight into different categories of late elementary students' text-learning strategy use during independent informative text-learning. - Four learner profiles (i.e., ways in which students combine certain text-learning strategies) can already be distinguished in late elementary education, i.e., the integrated strategy user, the information organizer, the mental learner, and the memorizer. - The learner profile differentiation was additionally validated with the analysis of overt text study traces and corroborated on a second independent sample. - More girls than boys were identified as integrated strategy users. More boys than girls were identified as mental learners.	- Motivational statements regarding independent text-learning were not retained from the analysis. - The use of self-reports is associated with some concerns. Future research should apply multiple forms of assessment, including also on-line measures of students' text-learning strategy use. - No statistically significant relationships were found between students' free text recall score and their learner profile. Further research should uncover the relationship between these profiles and multiple assessment measures more in-depth.	- The developed TLSI can be used to assess and report on the use of various text-learning strategies in late elementary education. - Students' initial study profiles should be considered when providing instruction in text-learning strategies. Furthermore, they offer a starting point to detect inefficient or underdeveloped text-learning strategies.
3	- Deep-level generative strategy use and the deliberative and strategic combination of various text-learning strategies are still in their infancy in late elementary education. - Based on the observed frequency of students' actual applied text-learning strategies as reflected in their think-aloud protocol, four strategy-repertoires could be distinguished (i.e., little or no strategy use, frequent use of one particular strategy, rich although less consequent strategy use, and deliberate and strategic strategy use). - Students' general achievement level is not related to either text-learning strategy use or belonging to a particular strategy-repertoire group.	- Using the think-aloud methodology might have been too intrusive for poor readers or some processes may not have been elicited. - Motivational text-learning strategies were not elicited in this study. - The sample size of his study is rather small. Future large-scale research with more homogenous achievement level groups is recommended to complement the research findings. - Students might have had different test expectations which might have influenced the results. Further research could	- This study provides a first explorative attempt to map students' graphical summarization process by means of digital pen movement analysis, an under investigated research area at this moment. - The study underlines the importance of initiating text-learning strategy use in general and graphical summarization skills in particular at the end of elementary education. Furthermore, the need for longitudinal intervention studies is emphasized. - The developed protocols and rubrics can be applied in further follow-up research and

		- Late elementary school students experienced great difficulty with constructing a graphical summary. - Low-achievers spent more time on orientation activities during pre-writing. - Students experience great difficulties with thinking aloud during schematizing (i.e., graphically summarizing text).	uncover students' strategy adoption more in detail and compare the uncovered strategy use in this study with strategy use addressing more diverse task demands. - The learning task was immediately followed by the schematizing task including the same text content. Follow-up research might use a different text in both tasks. - Future research with older participants and involving methods that stimulate students to explain their graphical summarization actions is encouraged to gain more insights in the graphical summarization process.	educational practice.
	4	- This comparison study provides evidence for the validity of the overt and covert cognitive strategy use in the Text-Learning Strategies Inventory. - This study illustrated the complementarity between self-report methods and think-aloud methods.	- Uncovering the relationship between self-reported metacognitive strategy use and observed metacognitive strategy use was more difficult. Therefore, future multi-method research is encouraged to further examine this correlation.	- The Text-Learning Strategies Inventory provides an acceptable alternative for the more time and labor-intensive think-aloud methodology, especially with regard to students' overt and covert cognitive text-learning strategy use.
RL2: Fostering generative text-learning strategies by means of a mind map strategy instruction				
Organizational learning strategy	5	- Students progress significantly in the application of the mind map rules. - Incorporating arrows and connectors to indicate text relationships and images and symbols in mind maps still seems rather difficult for this age group. - Students progress significantly in text processing by means of mind maps, that is, they depict more blanket terms (i.e., main ideas) from the text and better associate key words from texts. - Overall, children aged 11 and 12 are capable of independently constructing qualitatively good mind maps from informative texts after a ten-week researcher-delivered intervention.	- Research data were gather quantitatively. An additional qualitative study could provide more insight into students' motivational beliefs. - The sample size was rather small and no control condition was included in this study. Large-scale quasi-experimental research is therefore recommended. - No relationship between studying mind maps and text recall was investigated. Further research should unravel how working with mind maps stimulates students' conceptual understanding and text recall ability. - No specific learner characteristics were taken into account, which should be investigated in further research.	- Late elementary school children are able to learn to process informative texts by means of an explicit mind map instruction intervention within a consequent, systematic, and stimulating environment. - This study works on the existing gap in the literature regarding effective approaches to support children in processing and learning textual information in a structured way. - The effectiveness of mind mapping has only been scientifically investigated to a very limited extent. Therefore, this study enters upon an undeveloped and unexplored research domain for this age group.

Organizational learning strategy	6	- Evidence is provided for the effectiveness of teacher-delivered instructional approaches incorporating either researcher-provided (RPMM) or student-generated mind maps (SGMM) on students' graphical summarization skills (i.e., growth in their informative text traces, graphical design and graphical content) when contrasted against the control condition. - When mutually contrasting both experimental conditions, the greatest gains are shown for students in the student-generated mind map condition with regard to their informative text traces and their graphical design. As to the quality of the graphical content, no differences were found between both experimental conditions. - Gender and grade as student-level characteristics were most strongly related to students' graphical summarization skills. Girls evolve more in the RPMM condition as to the quality of the informative text traces, and more in the SGMM condition as to the graphical design. Sixth graders evolve significantly more than fifth graders in the SGMM condition as to the quality of the informative text traces and the graphical content. - No aptitude-by-treatment interactions were found.	- Graphical summarization was mainly approached through a product-oriented perspective. Future process-oriented research should complement the obtained findings. - The relationship between students' graphical summarization skills and learning performance remained unexplored. Further research should uncover the relationship between students' high quality graphical summaries and learning performance. - The school level could be investigated as an additional hierarchical level in the analysis in future research increasing the number of participating schools.	- The developed mind map strategy instruction, especially the one incorporating student-generated mind maps, can be used in educational practice to stimulate students' graphical summarization skills. - The developed analytic scoring rubrics show good to excellent interrater reliability and can be used in future research or in educational practice as a summative or formative assessment tool.
	7	- There is little evolution in the time spent on the pre- and post-writing phase and no significant differences in this respect between experimental and control condition students. - In-depth exploration of the construction phase revealed less versus more successful elaboration approaches (i.e., linear sequential, inconsiderate elaboration, structured approach, successive branch elaboration, and main idea elaboration approach). - Students from both experimental conditions mainly followed a successive branch elaboration approach. - Different construction steps can be identified in the construction of a graphical summary.	- Implementing the digital pen during test administration in class was associated with some concerns. Future research should test students individually using strict protocols. - The interpretation of post-writing strategic actions was difficult. The applied data-gathering technique should be substantiated with more objective data of students' strategic actions, i.e., retrospective interviews. - The sample size of this study is rather small. - Future research should investigate the relationship between graphical summarization and transcription skills.	- New possibilities for assessing pencast data are proposed. - This study is a first explorative attempt to unravel the developmental patterns in graphical summarization skills. In this respect, new possibilities for assessing pencast data are proposed. - Bridges are built between research and educational practice as the proposed educational measurement technique can be easily applied by teachers.

Meta-learning strategy	8	- Experimental condition students made a significantly greater progress from pre- to posttest in applying overt deep-level strategies when contrasted with control condition students. - Results showed the greatest gains and sustained effects in overt cognitive text-learning strategy use for students' in the researcher-provided mind map condition. - No significant differences were found in the evolution of the free recall score in favor of the experimental condition students. *Additional analysis (chapter 10)* - Gender and learner profile as student-level characteristics were found to be most strongly related to students' text-learning strategy use in the researcher-provided mind map condition. - General achievement level as a student-level characteristic was most strongly related to students' text-learning strategy use in the student-generated mind map condition.	- Some divergence between the self-reports and trace data must be acknowledged. In future intervention studies, it would be fruitful to apply the think-aloud methodology on smaller-subsamples. - Provided time for testing was constrained and only a free recall test was used to assess students' learning performance. Future research should include other tests and provide more study time. - No systematic direct observations were made regarding the assessment of treatment fidelity. Future research should keep on searching for valid means to obtain valid treatment fidelity data in relation to budgetary considerations.	- An effective teacher-delivered mind map strategy instruction is provided to stimulate students' overt deep-level strategy use, especially the strategy instruction incorporating researcher-provided mind maps. Mind mapping can in this way be incorporated as a meta-learning strategy into students' content courses. - Instructional designers are encouraged to incorporate worked-out mind maps into existing teaching methods with an increasing level of difficulty and accompanied with authentic student activities, in dialogue with subject matter-experts.
	9	- More students in the researcher-provided mind map condition spontaneously created a mind map when contrasted with students in the student-generated and control condition. - Predominantly girls spontaneously draw mind maps during independent text learning. Girls in both conditions also do appreciate the technique more than boys. - Students in the researcher-provided mind map condition appreciate the technique more and judge themselves as being more competent in creating mind maps then students in the student-generated condition. - Spontaneous mind map users appreciate using mind maps more and judge themselves as more competent in creating mind maps. - No significant differences were found as to free text recall between students who did and did not create a mind map for studying.	- The provided study time could have impeded students from the student-generated mind map condition to construct a mind map as a means for text studying. More in-depth qualitative research is necessary to determine students' motives to spontaneously use mind maps during text studying. - Students were tested on their free recall within a relatively short time span after learning the text. Administrating a delayed recall test is recommended for future research.	- Teachers are encouraged to integrate worked-out mind maps into their daily educational practice to stimulate students to transform linear texts into mind maps during independent learning. - Motivation related variables (e.g., self-efficacy, appreciation) should be taken into account in research and practice when aiming to induce spontaneous mind map use in late elementary education.

Nederlandstalige samenvatting
Summary in Dutch

Nederlandstalige samenvatting

Meten en bevorderen van strategieën voor het leren van teksten en grafische samenvattingsvaardigheden aan het eind van de lagere school. Een vergelijkende studie naar de impact van door de onderzoeker gegeven en door de leerlingen gegenereerde mind maps.

Inleiding

In dit proefschrift wordt gefocust op het meten en bevorderen van strategieën voor het verwerken en leren van tekstinformatie aan het eind van het lager onderwijs. Deze doelstelling kadert binnen het belang van ‘leren leren’, een sleutelcompetentie voor sociaal en economisch succes in de 21e eeuw, die gekenmerkt wordt door een exponentiële toename van kennis, informatie en te onderwijzen leerstof (Anderson, 2008; Fulk, 2000; Hoskins & Frederkisson, 2010; OECD, 2010). In dit opzicht is het begeleiden van leerlingen in het spontaan, zelfstandig toepassen en reguleren van effectieve strategieën voor het verwerken, onthouden en samenvatten van informatie cruciaal (OECD, 2010). Deze strategieën ontwikkelen wordt bijzonder belangrijk aan het eind van het lager onderwijs. Vanaf dan moeten leerlingen immers steeds meer informatieve teksten zelfstandig instuderen (Broer, Aarnoutse, Kieviet &, Van Leeuwe, 2002; Duchesne, Ratelle, & Roy, 2011; Meneghetti, De Beni, & Cornoldi, 2007). Het initiëren van een effectieve studiemethode is daarom een belangrijke onderwijsdoelstelling in de derde graad lager onderwijs (groep 7 en 8). Dit wordt tevens weerspiegeld in de leergebiedoverschrijdende eindtermen ‘leren leren’ in het Vlaamse lager onderwijs (Departement van Onderwijs en Vorming, 2008). Twee belangrijke beschouwingen kunnen worden afgeleid uit de theoretische en empirische literatuur rond zelfregulerend leren in het algemeen (bv. Boekaerts, 1999; Pintrich, 2000) en leerstrategiegebruik in het bijzonder (bv. Alexander, 1998; Mayer, 1996; Pressley, Borkowski, & Schneider, 1987; Weinstein, Jung, & Acee, 2011).

Ten eerste zijn leerlingen die effectief leren, strategisch lerende leerlingen. Deze leerlingen bezitten een breed strategierepertoire dat ze doelbewust inzetten bij het verwerken en instuderen van informatieve teksten (Alexander, 1998; Mayer, 1996; Pressley e.a., 1987; Weinstein e.a., 2011). Deze leerstrategieën worden op verschillende manieren gecategoriseerd in de literatuur (nl. naargelang van hun aard, de mate van actieve en diepgaande verwerking, hun waarneembaarheid of de leerfase waarin ze worden toegepast) en kunnen op verschillende manieren gecombineerd worden in leerprofielen of strategierepertoires (bv. Abar & Loken, 2010; Wade, Trathen, & Schraw, 1990). Binnen dit strategierepertoire wordt in het bijzonder gewezen op het belang van grafische samenvattingsvaardigheden (bv. Leopold, Sumfleth, & Leutner, 2013). Deze vaardigheden omvatten het kunnen samenvatten en transformeren van een informatieve tekst in een visueel coherente en hiërarchisch georganiseerde ruimtelijke structuur. Ondanks het belang van strategisch leren, ondervinden veel leerlingen studiemoeilijkheden door een vaak nog beperkt of inefficiënt strategiegebruik (Friend, 2001; OECD, 2010, Rachal, Daigle, & Rachal, 2007). Om het leerstrategiegebruik van lagere schoolkinderen echter ten volle in kaart te kunnen brengen, is er nood aan gepaste meetinstrumenten voor deze doelgroep.

Een tweede belangrijke beschouwing is dat onderwijsinterventies noodzakelijk zijn voor het stimuleren van strategieën voor het verwerken en leren van teksten, aangezien kinderen die strategieën meestal niet spontaan ontwikkelen (bv. Hall-Kenyon & Black, 2010; McNamara, Ozuru, Best, & O'Reilly, 2007). Hiervoor is het gebruik van grafische voorstellingen veelbelovend (bv. Dexter & Hughes, 2011; Nesbit & Adesope, 2006; Vekiri, 2002). In dit proefschrift wordt gefocust op het gebruik van mind maps (visueel-ruimtelijke, kleur- en beeldrijke schema's) (Buzan, 1974, 2005), als grafische samenvattingen. Hoewel deze reeds vaak gebruikt worden in de klaspraktijk, werd er nog slechts weinig empirisch onderzoek naar verricht. Meta-analyses rond het inzetten van 'maps' in het algemeen (bv. Nesbit & Adesope, 2006; Vekiri, 2002) en mind map onderzoek in het bijzonder (Farrand, Hussain, & Hennessy, 2002; Zipp, Maher, & D'Antoni, 2009) wijzen op hun effectiviteit als organisatiestrategie om het (grafisch) samenvatten van teksten te stimuleren. Verder zouden 'maps' ook ingezet kunnen worden als meta-leerstrategie, om leerlingen te leren hoe ze zelfstandig en betekenisvol kunnen studeren (Jackson, 2004). Er is echter nog onduidelijkheid over de meest effectieve instructiebenadering voor een mind map strategie-instructie, namelijk werken met door de onderzoeker gegeven mind maps enerzijds of door de leerlingen gegenereerde mind maps anderzijds (bv. Stull & Mayer, 2007). Verder kunnen ook specifieke leerlingkenmerken zoals geslacht, leerjaar, thuistaal, prestatieniveau en leerprofiel de effectiviteit van de instructie beïnvloeden.

Onderzoekslijnen

Bovenstaande beschouwingen leidden tot twee concrete onderzoekslijnen die dit proefschrift vorm gaven.

(1) Binnen een eerste onderzoekslijn werd gefocust op het *meten en in kaart brengen van strategieën voor het verwerken en leren van informatieve teksten*, waaronder grafische samenvattingsvaardigheden in het bijzonder. Nieuwe meetinstrumenten werden hiervoor ontwikkeld en gevalideerd, omdat er een gebrek is aan gepaste bestaande meetinstrumenten voor lagere schoolkinderen. Binnen deze onderzoekslijn werden drie empirische studies uitgevoerd. Gezien het belang van data-triangulatie, werden verschillende methodologische invalshoeken aangewend, namelijk de ontwikkeling van een zelfrapportage-vragenlijst enerzijds (hoofdstuk 2) en de analyse van hardop-denk

protocollen, traces (d.w.z. aantekeningen tijdens het studeren) en penbewegingen anderzijds (hoofdstuk 3). Binnen deze empirische hoofdstukken werd ook het strategierepertoire (leerprofiel) van leerlingen in kaart gebracht. Verder werd de samenhang onderzocht tussen de zelfrapportage over gehanteerde leerstrategieën enerzijds en de daadwerkelijk gehanteerde leerstrategieën zoals weerspiegeld in hardop-denk protocollen anderzijds (hoofdstuk 4).

(2) Een tweede onderzoekslijn richtte zich op het *bevorderen van tekstverwerkings- en tekstverwervingsstrategieën aan de hand van een grootschalige mind map interventiestudie*. Hierin werden de eerder ontwikkelde instrumenten gebruikt. Binnen deze onderzoekslijn werden twee subdoelen onderscheiden en vijf empirische studies uitgevoerd.

- *Subdoel 1*. Een eerste subdoel omvatte het bestuderen van mind mapping als een organisatiestrategie. Na een pilootstudie, waarin de basis werd gelegd voor de mind map strategie-instructie (hoofdstuk 5), werd mind mapping bestudeerd als organisatiestrategie ter bevordering van de grafische samenvattingsvaardigheden van de lagere schoolleerlingen (hoofdstuk 6 en 7).
- *Subdoel 2*. Een tweede subdoel omvatte het bestuderen van mind mapping als meta-leerstrategie, ter bevordering van een breder strategierepertoire van lagere schoolleerlingen (hoofdstuk 8 en 9).

Binnen hoofdstuk 6, 7, 8 en 9 komen volgende aspecten expliciet aan bod:

- De invloed van twee instructiebenaderingen op klasniveau, namelijk het werken met door de onderzoeker gegeven mind maps enerzijds en door de leerling gegenereerde mind maps anderzijds.
- De invloed van kenmerken op leerlingniveau, namelijk leerjaar, geslacht, thuistaal, prestatieniveau en leerprofiel.

Overzicht en discussie van de hoofdbevindingen

Onderzoekslijn 1: meten en in kaart brengen van strategieën voor het verwerken en leren van informatieve teksten

Binnen een eerste onderzoekslijn (hoofdstuk 2, 3 en 4) werd gefocust op het meten en in kaart brengen van strategieën voor het verwerken en leren van tekstinformatie aan het eind van het lager onderwijs. Gepaste meetinstrumenten zijn immers cruciaal om inzicht te krijgen in het initiële strategiegebruik van leerlingen en om interventie-effecten te kunnen documenteren (Boekaerts & Corno, 2005; Donker, de Boer, Kostons, & Dignath van Ewijk, 2014; Pressley, Graham, & Harris, 2006). Meetinstrumenten werden ontwikkeld vanuit verschillende methodologische perspectieven.

Met het oog op dataverzameling in grote groepen (Braten & Samuelstuen, 2007; Schellings, 2011) werd in hoofdstuk 2 gefocust op het ontwikkelen en valideren van een taakspecifieke zelfrapportage vragenlijst, namelijk de 'Text-Learning Strategies Inventory' (TLSI). De TLSI bestaat uit een specifieke leertaak (nl. het instuderen van een informatieve tekst), gevolgd door een vragenlijst omtrent de leerstrategieën toegepast tijdens het studeren. Een itempool van 66 items werd opgesteld op basis van de theoretische indeling van leerstrategieën enerzijds (bv. Weinstein e.a., 2011) en bestaande meetinstrumenten rond strategiegebruik anderzijds (bv. Biggs, 1987; Weinstein & Palmer, 2002). Een parallelanalyse en exploratieve factoranalyse bij een eerste steekproef van 896 leerlingen uit het vijfde en zesde leerjaar duidde op een 9-factorstructuur, bestaande uit 37 items. Een confirmatorische factoranalyse op een tweede onafhankelijke steekproef van 644 leerlingen bevestigde deze factorstructuur. Verder werd ook de invariantie van de factorstructuur voor jongens en meisjes aangetoond. Negen subschalen werden geïdentificeerd, namelijk de cognitieve strategieën 'samenvatten en schematiseren', 'aanduiden', 'herlezen', 'parafraseren', 'linken leggen met voorkennis', 'titels en prenten bestuderen' en de metacognitieve strategieën 'planmatige aanpak', 'monitoring' en 'zelf-evaluatie'. Naast het bevestigen van bestaande leerstrategie-opdelingen in de literatuur, werden ook enkele verschillen gevonden. Zo werd geen aparte subschaal voor 'herhalingsstrategieën' (Weinstein & Mayer, 1986) en geen strikte opsplitsing tussen oppervlakkige en diepgaande strategieën gevonden (Alexander, Dinsmore, Parkinson, & Winters, 2011). Dit biedt nieuwe inzichten in het leerstrategiegebruik van lagere schoolkinderen. In hoofdstuk 2 werden verder ook vier leerprofielen geïdentificeerd aan de hand van een hiërarchische clusteranalyse (steekproef 1) en een k-means clusteranalyse (steekproef 2): de geïntegreerde strategiegebruikers, strategiegebruikers die voornamelijk informatie organiseren, mentale leerstrategiegebruikers en memoriserende leerlingen. Bij het exploreren van de relatie tussen leerprofiel en het vrij herinneren van tekstinformatie werd een marginaal statistisch verschil gevonden, waarbij de geïntegreerde strategiegebruiker het meest uit de tekst bleek te onthouden. Verder werden meer meisjes geïdentificeerd als geïntegreerde strategiegebruikers en meer jongens als mentale leerstrategiegebruikers en memoriserende leerlingen.

In hoofdstuk 3 werd in een kleinschaliger onderzoek (20 leerlingen) gebruik gemaakt van de hardop-denk methodologie, trace methodologie (d.w.z. het bestuderen van aantekeningen tijdens het studeren en grafisch samenvatten) en het analyseren van penbewegingen tijdens het grafisch samenvatten. Aan de leerlingen werd gevraagd hardop denkend een leertaak en schematiseertaak uit te voeren. Tijdens de schematiseertaak gebruikten leerlingen een digitale pen. Een hardop-denk protocol en verschillende analytische scoringsrubrieken (nl. voor het scoren van de aantekeningen in de informatieve tekst, op het kladblad en in de grafische samenvatting) met een hoge interbeoordelaarsbetrouwbaarheid werden ontwikkeld met het oog op de data-analyse. Verder werd ook het bestaan van verschillende strategierepertoires geëxploreerd. Vier strategierepertoiregroepen werden onderscheiden en bevestigd aan de hand van een hiërarchische clusteranalyse: een eerste groep bezit een zeer beperkt strategierepertoire, een tweede groep maakt frequent gebruik van een welbepaalde leerstrategie, een derde groep bezit reeds een gevarieerd maar minder strategisch strategierepertoire en een vierde groep combineert verschillende leerstrategieën op een strategische manier. Verder werden ook de initiële grafische samenvattingsvaardigheden van leerlingen bestudeerd aan de hand van online analyses (d.w.z. analyses van het proces, tijdens de taakuitvoering) en offline analyses (d.w.z. analyses van het product, na de taakuitvoering). Offline analyses wezen uit dat zeer weinig leerlingen er reeds in slagen een goed hiërarchische georganiseerde grafische samenvatting van tekstinformatie te maken. Uit de online analyses bleek dat het hardop denken tijdens het samenvatten zeer moeilijk verloopt binnen deze leeftijdsgroep. Het analyseren van digitale penbewegingen blijkt dan weer een veelbelovende manier om inzicht te krijgen in het dynamische samenvattingsproces. Deze analyses wezen uit dat slechts weinig leerlingen expliciet gebruik maken van metacognitieve strategieën tijdens het schematiseren (het plannen of herbekijken van de samenvatting). Ook het algemene prestatieniveau van leerlingen (nl. hoog-, doorsnee- of laagpresteerders) werd als specifiek leerlingkenmerk bestudeerd. Het algemene prestatieniveau blijkt niet gerelateerd aan het behoren tot een welbepaald strategierepertoire groep. Verrassend genoeg echter, bleken leerlingen die over het algemeen lager presteren, meer tijd te besteden aan de fase voor het daadwerkelijk samenvatten (pre-writing phase).

Drie belangrijke vaststellingen komen naar voren bij het vergelijken van de resultaten uit hoofdstuk 2 en 3. Ten eerste zijn er opvallende parallellen tussen de classificatie van leerstrategieën in de zelfrapportage-vragenlijst enerzijds en het hardop-denk protocol anderzijds. In beide studies werden die namelijk het best gekarakteriseerd naargelang van hun aard (cognitief en metacognitief) en waarneembaarheid (observeerbaar en minder observeerbaar). Ten tweede werden in beide studies geen motivationele leerstrategieën geïdentificeerd. Mogelijk is dit te wijten aan de eerder onbewuste aanwezigheid van motivatie zonder actieve regulatie bij deze leeftijdsgroep (Wolters, Benzon, & Arroyo-Giner, 2011). Ten derde kunnen vier algemene groepen leerlingen geïdentificeerd worden wanneer de leerprofielen en strategierepertoires uit hoofdstuk 2 en 3 met elkaar vergeleken worden aan de hand van twee dimensies, nl. de diversiteit van de gebruikte leerstrategieën enerzijds en de mate van diepgaande toepassing van deze strategieën anderzijds. Een eerste groep leerlingen bezit een basisniveau van leerstrategieën en maakt veelal gebruik van slechts één strategie bij het instuderen van teksten. Een tweede groep gebruikt al meer leerstrategieën, maar past deze voornamelijk oppervlakkig toe. Een derde groep past een of twee leerstrategieën reeds diepgaander toe. Een vierde groep vertoont het meest wenselijke profiel, door het strategisch toepassen van verschillende leerstrategieën.

Zowel het gebruik van de zelfrapportagemethode (hoofdstuk 2) als de hardop-denk methode (hoofdstuk 3) hebben enkele voor- en nadelen. Vooral het gebruik van zelfrapportage ligt in de literatuur onder vuur (Braten & Samuelstuen, 2007). Daarom werd geopteerd om de validiteit van de zelfrapportagevragenlijst bijkomend te bestuderen door de samenhang tussen de zelf-gerapporteerde en de geregistreerde leerstrategieën in hardop-denkprotocollen te onderzoeken (20 leerlingen). Er werd vooral bijkomende validiteit gevonden voor de zelf-gerapporteerde cognitieve leerstrategieën. Het onderzoeken van de samenhang tussen de gerapporteerde en geregistreerde metacognitieve leerstrategieën bleek moeilijk, waardoor de interpretatie van het zelf-gerapporteerd metacognitief leerstrategiegebruik van deze leeftijdsgroep met omzichtigheid moet gebeuren.

De belangrijkste resultaten van de drie empirische studies binnen de eerste onderzoekslijn kunnen als volgt samengevat worden:

Wat betreft het *meten* van strategieën voor het verwerken en verwerven van tekstinformatie aan het eind van het lager onderwijs:

1. De ontwikkelde instrumenten (d.i. de zelfrapportagevragenlijst, het hardop-denk protocol, de analytische scoringsrubrieken) zijn gevalideerde meetinstrumenten die kunnen worden toegepast in toekomstig onderzoek om offline data (omtrent het product van leerlingen) en online data (omtrent het doorlopen proces van leerlingen) te vergaren.
2. De resultaten verkregen aan de hand van de ontwikkelde meetinstrumenten benadrukken het belang van het zo vroeg mogelijk oriënteren van studenten naar het leren van teksten. Leerlingen uit het vijfde en zesde leerjaar bezitten immers nog zeer beperkte leerstrategieën, die veeleer oppervlakkig en niet strategisch toegepast worden.
3. Vooral de grafische samenvattingsvaardigheden van leerlingen zijn onderontwikkeld.

Wat betreft het *in kaart brengen van* strategieën voor het verwerken en verwerven van tekstinformatie aan het eind van het lager onderwijs:

4. Aan het eind van het lager onderwijs kunnen reeds verschillende leerprofielen of strategierepertoires onderscheiden worden.
5. Het is hierbij belangrijk om zowel de mate van actieve en diepgaande verwerking als de variëteit aan toegepast leerstrategiegebruik in acht te nemen.

Onderzoekslijn 2: het bevorderen van tekstverwerkings- en tekstverwervingsstrategieën aan de hand van een mind map strategie-instructie

Rekening houdend met de veelbelovende rol van het gebruik van grafische voorstellingen om het verwerken en leren van teksten te ondersteunen (bv. Nesbit & Adesope, 2006; Vekiri, 2002), werd binnen een tweede onderzoekslijn de effectiviteit van een mind map strategie-instructie onderzocht. Voorafgaand aan de grootschalige interventiestudie, werd een pilootstudie opgezet bij 62 leerlingen uit het vijfde en zesde leerjaar (hoofdstuk 5). Deze had als doel te verifiëren of 11- en 12-jarigen reeds in staat zijn een mind map (gebruikt als grafische samenvatting) te maken van een informatieve tekst. Hiervoor gaf de onderzoeker gedurende tien weken instructie in vier authentieke klassen. Repeated measures analyses toonden aan dat leerlingen in deze leeftijdsgroep reeds informatieve teksten kunnen leren verwerken aan de hand van mind mapping. De ontwikkelde strategie-instructie diende als basis voor de ontwikkeling van twee mind map instructiebenaderingen in het verdere onderzoek.

Om mind mapping als een organisatiestrategie en meta-leerstrategie te onderzoeken (cf. subdoel 1 en 2 binnen de tweede onderzoekslijn) werd een interventiestudie opgezet met twee experimentele condities en een controleconditie. In de twee experimentele condities implementeerde de leerkracht een welbepaalde mind map strategie-instructie, nl. een strategie-instructie waarbij door de onderzoeker gegeven mind maps werden geïntegreerd en een strategie-instructie waarbij door de leerling gegenereerde mind maps werden geïntegreerd. Leerlingen in de controleconditie kregen geen expliciete mind map strategie-instructie. De data voor de empirische mind map studies werden verzameld bij 644 leerlingen uit het vijfde en zesde leerjaar van 17 verschillende scholen. Er zaten respectievelijk 213 en 219 leerlingen in de eerste en tweede experimentele conditie en 212 leerlingen in de controleconditie. Tijdens een pretest (voor de start van de interventie), een posttest (meteen na de tien weken durende interventie) en een retentietest (3 maanden na afloop van de interventie) werd een leertaak en een grafische samenvattingstaak van alle leerlingen afgenomen. De leertaak bestond uit het zelfstandig instuderen van een informatieve tekst gevolgd door het invullen van de zelfrapportagevragenlijst en een test waarin de leerlingen werd gevraagd om alle informatie te noteren die ze zich nog herinnerden uit de tekst. De grafische samenvattingstaak bestond uit het zelfstandig grafisch samenvatten van een informatieve tekst.

In hoofdstuk 6 en 7 werd gefocust op het eerste subdoel binnen de tweede onderzoekslijn, nl. het onderzoeken van mind mapping als een organisatiestrategie ter bevordering van grafische samenvattingsvaardigheden. Hiervoor werden de data van de grafische samenvattingstaak geanalyseerd. In hoofdstuk 6 werden gedetailleerde analyses uitgevoerd op de aantekeningen van leerlingen (trace analyses) in de informatieve tekst en op hun grafische samenvatting (de kwaliteit van de vormgeving enerzijds en de inhoudelijke kwaliteit anderzijds). Multilevel piecewise growth analyses toonden een significant grotere en langdurige groei aan van de grafische samenvattingsvaardigheden van leerlingen in de experimentele condities. In het bijzonder leerlingen die werken met zelfgegeneerde mind maps gaan doelbewuster en strategischer aan de slag tijdens het zelfstandig samenvatten. Zo schenken zij bijvoorbeeld meer aandacht aan belangrijke voorbereidende acties (bv. kernwoorden aanduiden in de informatieve tekst), creëren ze qua vormgeving de meest kwaliteitsvolle mind maps en identificeren ze inhoudelijk de beste overkoepelende hoofdideeën. Het valt echter op dat leerlingen die werkten met gekregen mind maps de leerlingen die werkten met zelfgemaakte mind maps overtreffen in het integreren van tekeningen en symbolen in hun grafische samenvatting, een vaardigheid waarvan de voordelen voor het verwerken en leren van teksten reeds aangetoond werden (Anderson & Hide, 1971; Leopold e.a., 2013). Behalve het formuleren van overkoepelende hoofdideeën, is de inhoudelijke kwaliteit van de samenvatting in beide experimentele condities even goed. Meisjes in de eerste experimentele conditie (gekregen mind maps) behaalden hogere scores dan jongens in deze conditie wat betreft de kwaliteit van aanduidingen in de informatieve tekst. Meisjes in de tweede experimentele conditie (zelfgemaakte mind maps) behaalden dan weer hogere scores dan jongens in deze conditie wat betreft de vormgeving van hun samenvatting. Verder evolueerden zesdeklassers significant meer dan vijfdeklassers in de tweede experimentele conditie op het vlak van aantekeningen in de informatieve tekst en de inhoudelijke kwaliteit van de samenvatting. Verrassend genoeg en in tegenstelling tot eerder onderzoek (bv. Hattie, Biggs, & Purdie, 1996) werden geen differentiële effecten van de interventie gevonden voor jongens en meisjes, vijfdeklassers en zesdeklassers, leerlingen met een verschillend prestatieniveau of leerlingen met een andere thuistaal dan het Nederlands.

Een kleinere steekproef (n = 18) binnen dit grootschalig onderzoek werd gevraagd om de grafische samenvattingstaak uit te voeren met een digitale pen. Aan de hand hiervan werd in een deelstudie het dynamisch grafisch samenvattingsproces diepgaander onderzocht. Er werden geen significante verschillen vastgesteld tussen studenten uit de experimentele en de controleconditie wat betreft de regulatieve processen die het samenvatten begeleiden (d.i. het plannen en reviseren van de samenvatting). Een gedetailleerde studie van het constructieproces op zich wees echter wel op het bestaan van verschillende constructiestappen en verschillende manieren om een grafische samenvatting uit te werken. Deze verschillende aanpakken bleken ook gerelateerd te zijn aan de uiteindelijke kwaliteit van de grafische samenvatting. Op die manier konden minder en meer effectieve uitwerkingswijzen van elkaar onderscheiden worden. Deze nieuwe inzichten laten toe belangrijke beginnersmoeilijkheden te identificeren (Hilbert & Renkl, 2008).

In hoofdstuk 8 en 9 werd gefocust op het tweede subdoel binnen de tweede onderzoekslijn, nl. het onderzoeken van mind mapping als een meta-leerstrategie ter bevordering van een breder strategierepertoire. Hiervoor werden de data van de leertaak (d.i. gegevens vergaard aan de hand van de zelfrapportagevragenlijst en studie-aantekeningen in de tekst en op het kladblad) geanalyseerd aan de hand van multilevel piecewise growth modeling. In hoofdstuk 8 werd concreet nagegaan of de mind map strategie-instructie ook het spontaan toepassen van cognitieve en metacognitieve strategieën kan uitlokken tijdens een zelfstandige leertaak. Tegen de verwachtingen in, vertoonden de leerlingen uit de eerste experimentele conditie, die werkten met door de onderzoeker gegeven mind maps, de grootste en meest langdurige groei op het vlak van het observeerbaar diepgaand leerstrategiegebruik dat spontaan werd toegepast. Er werden echter weinig tot geen significante verschillen gevonden tussen de experimentele en controlecondities op het vlak van het metacognitief strategiegebruik (d.i. planmatige aanpak, monitoring en zelf-evaluatie). Verder werden, net als in eerder onderzoek (bv. Frazier, 1993; Wade e.a., 1990), voor de experimentele condities geen significante verschillen gevonden wat betreft de hoeveelheid onthouden tekstinformatie. De 'utilization deficiency' wijst er in dit opzicht op dat het mogelijk is dat leerlingen niet meteen voordeel halen uit hun gebruikte diepgaandere leerstrategieën (Bjorklund, Miller, Coyle, & Slawinski, 1997). Verder werden binnen de experimentele conditie waarin door de onderzoeker gegeven mind maps werden gebruikt voornamelijk invloeden van geslacht en leerprofiel vastgesteld op de onderzochte variabelen. In de tweede experimentele conditie speelde voornamelijk het prestatieniveau van de leerlingen een rol.

In hoofdstuk 9 werd het spontaan gebruik van mind maps bij het instuderen van een informatieve tekst nader bestudeerd. Hierbij werden ook motivationele variabelen (d.i. de appreciatie van de mind map techniek en de eigen bekwaamheidsperceptie in het gebruik van mind maps) in rekening gebracht. Analyses wezen uit dat leerlingen die spontaan mind maps maakten bij het studeren de techniek meer appreciëren en zichzelf ook meer bekwaam achten in het maken van mind maps. Verder zijn het voornamelijk meisjes en leerlingen uit de eerste experimentele conditie die spontaan mind maps maken tijdens het studeren. Er werd geen significant verschil gevonden in de hoeveelheid onthouden tekstinformatie tussen leerlingen die wel of geen mind map creëren tijdens het studeren.

De belangrijkste resultaten van de empirische studies binnen de tweede onderzoekslijn kunnen als volgt samengevat worden:

Wat betreft het gebruik van mind mapping als een *organisatiestrategie*:

1. Leerlingen aan het eind van het lager onderwijs kunnen reeds zelfstandig een mind map (gebruikt als grafische samenvatting) construeren van een informatieve tekst.
2. De grootste groei in grafische samenvattingsvaardigheden werd gevonden voor leerlingen die tijdens de strategie-instructie werkten met zelf gegenereerde mind maps. Zij gaan tijdens het zelfstandig samenvatten doelbewuster en strategischer aan de slag.
3. Geslacht blijkt het sterkst gerelateerd te zijn aan de grafische samenvattingsvaardigheden van leerlingen in de eerste experimentele conditie. In de tweede experimentele conditie is dit geslacht en leerjaar.
4. Er werden geen differentiële effecten van de interventie gevonden voor jongens en meisjes, vijfdeklassers en zesdeklassers, leerlingen met een verschillend prestatieniveau of leerlingen met een andere thuistaal dan het Nederlands.
5. Er werd weinig evolutie gevonden in het toepassen van regulerende vaardigheden (d.i. plannen en reviseren) tijdens het construeren van een grafische samenvatting.

Wat betreft het gebruik van mind mapping als een *meta-leerstrategie*:

6. De grootste groei en het meest langdurige effect in het spontaan diepgaand cognitief leerstrategiegebruik werd gevonden voor leerlingen die tijdens de strategie-instructie werkten met door de onderzoeker gegeven mind maps.
7. Er werden weinig tot geen significante effecten gevonden in de groei van metacognitief leerstrategiegebruik en de hoeveelheid onthouden tekstinformatie van leerlingen in beide experimentele condities.
8. Geslacht en leerprofiel zijn het sterkst gerelateerd aan spontaan strategiegebruik in de eerste experimentele conditie.
9. Algemeen prestatieniveau is het sterkst gerelateerd aan spontaan strategiegebruik in de tweede experimentele conditie.

10. Leerlingen die spontaan mind maps construeren tijdens het studeren zijn voornamelijk meisjes en leerlingen uit de eerste experimentele conditie. Spontane mind mappers appreciëren de techniek ook meer en achten zichzelf meer competent in het creëren van mind maps.

Algemeen besluit

Dit proefschrift focust op twee onderzoekslijnen die voortvloeien uit twee belangrijke beschouwingen in het onderzoek naar zelfregulerend leren in het algemeen en leerstrategiegebruik in het bijzonder. Enerzijds wijst de literatuur op het belang van een breed strategierepertoire voor het verwerken en verwerven van informatieve teksten, anderzijds op de nood aan onderwijsinterventies om deze te stimuleren. Binnen een eerste onderzoekslijn wordt gefocust op het meten en in kaart brengen van strategieën voor het leren van teksten en grafische samenvattingsvaardigheden vanuit verschillende methodologische invalshoeken. Hierbinnen werden drie empirische studies uitgevoerd. De instrumenten die hierin ontwikkeld werden, kunnen in toekomstig onderzoek naar leerstrategiegebruik in het lager onderwijs gebruikt worden en staan toe parallellen te trekken met bestaande theoretische modellen van strategiegebruik. Een tweede onderzoekslijn richt zich op het bevorderen van deze strategieën aan de hand van een mind map strategie-instructie. Binnen deze onderzoekslijn werden vijf empirische studies uitgevoerd waarbinnen mind mapping als organisatiestrategie en meta-leerstrategie werd bestudeerd. De ontwikkelde mind map strategie-instructie verrijkt bestaand onderzoek rond het aanleren van leerstrategieën in het algemeen en (grafische) samenvattingsvaardigheden in het bijzonder. Er werd immers aangetoond dat deze strategie-instructie grafische samenvattingsvaardigheden kan stimuleren en leerlingen kan begeleiden in het zelfstandig toepassen van diepgaande strategieën tijdens het studeren. Dit proefschrift leidt dan ook tot een belangrijke hernieuwde interesse in het gebruik van maps als meta-leerstrategie, vooral wanneer gegeven mind maps worden gebruikt.

De beperkingen gerelateerd aan de studies opgenomen binnen dit proefschrift betekenen belangrijke startpunten voor toekomstig onderzoek. Onderzoekers worden dan ook aangespoord om met een gepaste methodologie verder onderzoek te verrichten naar de invloed van leerlingkenmerken, kenmerken van de tekst en de grafische samenvatting op de cognitieve, metacognitieve en motivationele strategieën voor het verwerken en verwerven van informatie uit informatieve teksten. Interdisciplinair mixed-method onderzoek lijkt hierbij aangewezen. Leerkrachten en leerlingbegeleiders worden aangemoedigd om aan de hand van de onderzoeksinstrumenten de leerstrategieën van leerlingen in kaart te brengen en te evalueren. Verder worden leerkrachten aangespoord mind mapping op een strategische manier in te zetten in de dagelijkse klaspraktijk om leerlingen te helpen informatieve teksten aan te pakken. Het leermateriaal ontwikkeld in dit proefschrift kan hiervoor aangewend worden.

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Academic output

Academic output

Output integrated in this dissertation

Journals (a1)

Merchie, E., Van Keer, H., & Vandevelde, S. (2014). Development of the Text-Learning Strategies Inventory: Assessing and profiling learning from texts in fifth and sixth grade. *Journal of Psychoeducational Assessment.* 1-15. Advanced online publication. doi: 10.1177/0734282914525155

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Merchie, E., & Van Keer, H. (2014). Mind mapping as a meta-learning strategy: Stimulating pre-adolescents' text-learning strategies and performance? Manuscript resubmitted for publication in *Instructional Science* (after a first revision based on the reviewers' comments).

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Conference contributions

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